THE ENGINEER

FEBRUARY 26, 1954

Institution of Civil Engineers

MR. E. GRAHAM CLARK, C.B.E., is this year retiring from his post as Secretary of the Institution of Civil Engineers. Mr. Graham Clark has had a long and distinguished career on the staff of the Institution, and has been its Secretary since 1937, when he succeeded Dr. H. H. Jeffcott. He was educated at Felsted School and Durham University, and served his pupilage with the consulting engineer J. Mitchell Moncrieff, to whom he later became an assistant. Mr. Graham Clark served as a commissioned officer with the 50th (Northumbrian) Division, during the 1914–18 war. He was subsequently appointed Chief Technical Assistant at the Institution, where, as we have already noted, he became Secretary in 1937. He is to be succeeded by Mr. Alexander McDonald. Mr. McDonald was born in 1903 and educated at Fraserburgh Academy and Edinburgh University, where he graduated in 1923. After a two-year period of pupilage he joined the Nigerian Public Works Department in 1925, where he has since served in various capacities, his present position being Inspector-General of Public Works.

Launch of Tanker "World Harmony"

TUESDAY, February 16th, was a royal occasion at the Naval Yard of Vickers-Armstrongs, Ltd., Newcastle upon Tyne, when H.R.H. the Duchess of Kent performed the naming ceremony of the oil tanker "World Harmony." This ship, which is the largest tanker launched from a British yard, is the eighth tanker built for the same owner, Mr. Stavros Niarchos, and when she and two larger ships, now building at Barrow, are completed, some 300,000 deadweight tons of tankers will have been constructed for the same group, World Tankers Corporation, within a short period. The main dimensions of the vessel are: length overall 663ft, length between perpendiculars 635ft, breadth moulded 86ft, depth moulded 45ft 9in, and deadweight 33,000 tons on a draught of 45ft 9in. Construction of the hull is on the orthodox longitudinal framing system over the length of the cargo tanks, of which there are thirty, and the transverse system forward and aft of them. Rapid discharge of the cargo oil is ensured by three turbine-driven horizontal, centrifugal pumps, each having a water capacity of 1000 tons per hour, supplemented by two steam-driven vertical stripping pumps of 150 tons per hour. Parsons Marine Steam Turbine Company, Ltd., has constructed the main propelling machinery, consisting of a single set of double-reduction geared turbines which drive the propeller at 100 r.p.m., when developing normal power of 12,500 s.h.p. and 103 r.p.m. when developing a maximum of 13,750 s.h.p., while the astern turbine is capable of developing 45 per cent of the normal ahead power. The h.p. turbine, of impulse pattern, and the l.p. turbine, of reaction pattern, work in series and operate with superheated steam at a pressure of 850 lb per square inch and a temperature of 850 deg. Fah., supplied by two Foster-Wheeler "D" water-tube boilers operating under Howdens forced draught. Electrical power for the various auxiliary machinery units is provided by two turbine-driven alternators each of 500kW.

Launch of Cunard Liner "Saxonia"

THE first of three Cunard liners specially designed for service up the St. Lawrence to Quebec and Montreal was launched on Wednesday of last week from the yard of John Brown and Co. (Clydebank), Ltd., and was named "Saxonia" by Lady Churchill. In adopting this name the Cunard Line has revived that of an earlier ship which was built at the same yard, some fifty-four years ago, for the New York and Boston service and was broken up in 1925. The first "Saxonia" had a length of 580ft by 64ft beam, a gross tonnage of 14,000 and a speed of about 15 knots, while the new ship has a length overall of 608ft 3in, a length between perpendiculars of 570ft by 80ft breadth moulded and 46ft 3in depth moulded, a gross tonnage of 22,000 and a speed of 20 knots. Other comparisons between the old and the new show that whereas the first ship carried about 1500 passengers in three classes, the present one provides accommodation for 125 first-class and 800 tourist-class passengers. In addition the old ship was propelled by quadruple expansion engines taking steam at 210 lb per square inch from nine boilers, whereas the present-day propulsion unit consists of double-reduction geared turbines taking steam at over 500 lb per square inch from four boilers. When completed the "Saxonia" will have a single distinctive funnel, a mast placed abaft the bridge, six hatches serving 300,000 cubic feet of cargo space, nine decks and Denny-Brown stabilisers, while the staterooms and public rooms for both classes of passengers will have controllable ventilation. The shipbuilders are also constructing the main propelling machinery, consisting of two sets of high and low pressure turbines driving propellers at 135 r.p.m. through double-reduction gearing. Four end-fired water-tube boilers supply steam at 550 lb per square inch and 800 deg. Fah. and the electrical power for ship and domestic services, deck and auxiliary machinery will be supplied by four turbine-driven generators each giving 750kW.

Lloyd's Register Launch Returns for 1953

DURING this week Lloyd's Register of Shipping has issued its "Annual Summary of Merchant Ships Launched in the World During 1953," which takes into account all ships upwards of 100 tons gross. During the year some 85 steamships of 521,918 tons and 135 motorships of 795,545 tons, making a total of 220 ships of 1,317,463 gross tons, were launched in Great Britain and Northern Ireland. This total is 14,915 tons more than for 1952 and represents 25·9 per cent of the world output compared, with 29·6 per cent in 1952. Seven ships of more than 20,000 tons, four of which are oil tankers, are included in the returns, which list 4 ships between 15,000 and 20,000 tons each, 52 ships between 10,000 and 15,000 tons, 12 ships between 8000 and 10,000 tons, and 40 ships between 4000 and 8000 tons each. A total of 77 oil tankers of 762,442 tons was launched, made up of 24 steamships of 240,138 tons and 53 motorships of 522,304 tons and representing an increase of 116,414 tons, compared with 1952 and 57·9 per cent of the total shipbuilding output for last year. Of the total tonnage launched, 54 ships of 364,591 tons, or 27·7 per cent, were for registration abroad, including 235,269 tons of oil tankers. The ships launched abroad totalled 923 of 3,778,587 tons, consisting of 192 steamships of 1,615,538 tons and 731 motorships of 2,163,049 tons, and representing an increase of 685,557 tons over the 1952 returns. The total, which excludes China, Poland and Russia, is the highest reached abroad since 1920 and a table gives the outputs of the various countries with the corresponding figures for 1952, while a list records the names of 13 ships of over 20,000 tons, all of which except one are oil tankers. There were also launched 30 ships of between 15,000 and 20,000 tons each, 102 ships between 10,000 and 15,000 tons, 49 ships between 8000 and 10,000 tons, and 124 ships of between 4000 and 8000 tons. The oil tankers totalled 202 ships of 2,099,927 tons, consisting of 72 steamships of 1,097,695 tons and 130 motorships of 1,002,232 tons, representing 55·6 per cent of all tonnage launched abroad and an increase of 730,609 tons, compared with 1952.

Standardisation in the U.S.A.

THE report of a mission sent to the United States to study the organisation of standardisation has now been published by the Organisation for European Economic Co-operation. The mission was divided into a number of groups to study various aspects of standardisation. The first group examined the general development of standardisation in the United States, and the other groups dealt with machine tools, screws, ball bearings, iron and steel, and petroleum. In its report the first group describes the complexities encountered in connection with standardisation in the United States. It points out that the American Standards Association was formed with Government participation to co-ordinate the standardising activities of technical societies and other bodies. The necessity of this co-ordinating work, it states, has never been challenged, but much standardisation of a national character still remains in the hands of individual bodies, and the position of the A.S.A. has been somewhat weakened by the withdrawal of direct Government participation following legal investigations arising out of the Anti-Trust Laws. The result has been that national co-ordination of standards is not so far advanced as in most European countries. The application of standards in the United States is stated by the mission in its conclusions to be widespread, but by no means consistent. American industry, it is suggested, pays little attention to standardisation on a broad basis, such as international standardisation, if no immediate advantages can be seen.

Safety on the Road

DR. W. H. GLANVILLE, Director of Road Research of the D.S.I.R., delivered a lecture with the above title on Monday last at the Royal Society of Arts. The lecture is the first of a series of three on safety in transport generally. Dr. Glanville's review of the present condition of the roads, and of accidents and their possible remedies, contained many interesting facts and statistics of the various facets of this important social problem. He remarked that road safety was not unlike other public health problems, which had also largely grown with the industrial and technological development of the past one hundred years or so. Many of these problems had been solved, he said, and we were providing ourselves with a healthier environment and way of life, but we still maintained a system of moving ourselves and our goods on our roads which caused over 5000 deaths and over 220,000 injuries last year. The days were past, Dr. Glanville continued, when any one of us would argue that our roads were anything but totally inadequate for the traffic they carried, but the public attitude to road problems was such that road reconstruction was not given a high priority in relation to other matters; of recent years a more favourable atmosphere had been developing, but no great progress could be made, Dr. Glanville contended, until the public attitude changed very much more. During the course of his lecture Dr. Glanville spoke of the two main sides of the question, the equipment (the roads and the vehicles) and the human element. The possibilities of research and the analysis of the behaviour and defects of the road, and of various aspects of the vehicle were given in some detail during the course of the lecture, followed by some pertinent remarks on the second side of the question, concerned with the behaviour of the road user.

Effectiveness of Vibration of Concrete

By J. M. PLOWMAN, B.Sc.(Eng.), Ph.D., A.C.G.I., D.I.C.

An investigation into the effectiveness of the compaction of concrete specimens achieved with a vibrating table is examined in this article. Accelerometers were embedded in the concrete and acceleration contours for the various specimens were obtained.

WHEN concrete is compacted by vibration the vibration may be applied in several ways. If the casting is compact and weighs less than, say, 1 to 1½ tons, it can be vibrated on a vibrating table or tables; if larger, or if it is necessary to cast it *in situ*, then immersion or external shutter vibrators are used. The three methods have different characteristics and it is doubtful whether many of the results obtained for one are applicable to the others. There is a fourth method of vibration, namely, the surface vibration of road slabs. This is highly specialised and has been very completely dealt with by Dr. R. H. H. Kirkham in numerous papers. It is the author's intention to discuss the problems of the three kinds of vibration with particular attention to that of the vibrating table, which is widely used in precasting factories throughout the country.

Vibration has been used to compact concrete for some sixty years, but little or no research has been carried out to determine the behaviour of concrete as a mass or as a collection of particles under vibration. The Research Committee of the Institution of Civil Engineers and D. A. Stewart published some results in 1937 for concrete cubes vibrated on two types of small vibrating table, which were a useful foundation on which to build knowledge of the subject. Unfortunately, there has been little further work on the problems since then, and after five years of work in the field the author would say that our knowledge of the subject is rather small.

To date all the work carried out on the subject, including most of the author's, has related various phenomena produced in the concrete by vibration to the frequency and acceleration of the vibrating unit, which in almost all cases has been a small vibrating table. This elementary work assumes that the whole of the concrete vibrated, usually small cubes, vibrates at the same frequency and acceleration as the table, which is approximately true. The question must now be asked whether the mass of concrete in a large mould, say, for simplicity, vibrating on a large table with a uniform acceleration across its surface, behaves as one solid mass with each particle having a similar acceleration, frequency and phase. If the frequency of the particles is different to that of the table then the acceleration will most probably differ also, and if the acceleration varies then since the time required for compaction

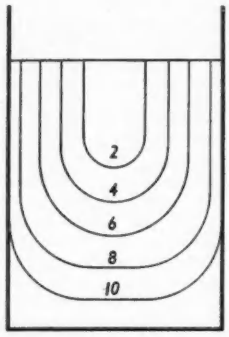


Fig. 1—Assumed Acceleration Contours

varies inversely with the acceleration of the mix, some parts of the casting will be fully compacted before others. If vibration is stopped before all portions are fully compacted, then a casting will result with strength varying throughout, similar to a case-hardened steel. It is suggested that such concrete is not desirable and that all castings should be as uniform as possible.

After consideration of the foregoing the author concluded that the acceleration of a mix would vary considerably throughout the mass of the casting. The acceleration would diminish with increasing distance vertically from the table top due to the absorption of energy by the plastic mass, and also the acceleration would be greater at the sides where the vibration would be imparted to the concrete by the skin friction between the concrete and the mould sides, which, being rigid, would not absorb energy to such an extent as the plastic concrete. These were merely ideas not based on fact and may be summed up as acceleration contours as in Fig. 1, where the maximum acceleration is given a value of 10.

If these ideas were correct, then it was important to know the minimum value of the acceleration in the mix with respect to that applied, since if this value were too low compaction would be long delayed or never achieved. It was to determine the validity of these ideas that the following experimental work was planned and carried out at King's College, London.

The first requirement was a means of measuring the acceleration and frequency of the vibration inside the concrete at any given point. To do this an accelerometer was evolved working on similar principles to that developed at the Road Research Laboratory by Dr. Whiffen and Kirkham, consisting of a square crystal of Rochelle salt clamped on two sides and allowed to vibrate about a diagonal. The potential caused by the vibration of the crystal is fed through a junction box and integrator to the vertical plates of an oscillograph. Six accelerometers were used, each being calibrated for acceleration against deflection of the oscillograph trace by means of a standard vibrating unit, for a given frequency. It was possible, not only to measure the acceleration, frequency and amplitude of the vibration in this way, but also to obtain a trace of the actual vibration of the concrete particles, by means of a camera attachment to the oscillograph.

One of the difficulties involved in experimental work of this nature is the large volume of concrete which has to be handled in the short space of time of the experiment, large, that is, from the point of view of a small laboratory with a mixer of 100 lb capacity. It was decided to investigate the following :—

(1) The effect of varying the depth of mix on the acceleration with constant mix, water cement ratio and width of mould.

(2) The effect of varying the width of

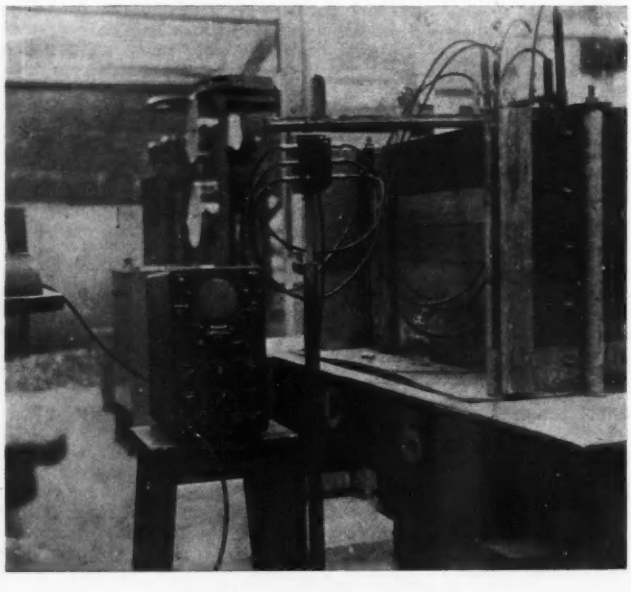


Fig. 2—Vibration Test Apparatus

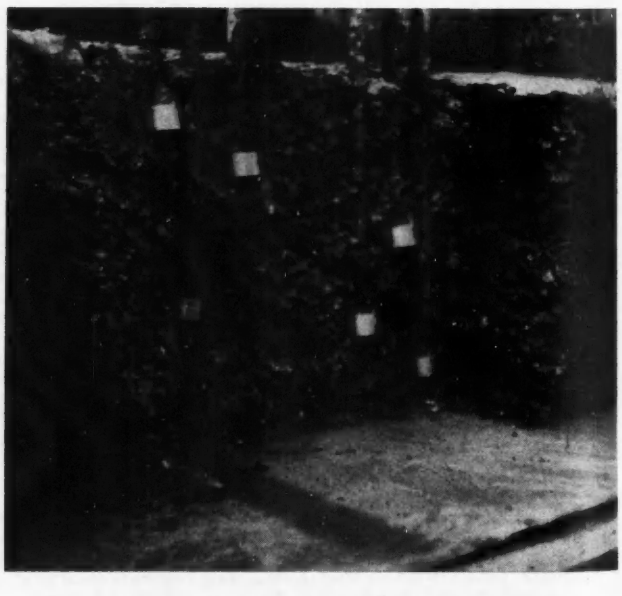


Fig. 3—Accelerometers Embedded in Concrete Test Specimen

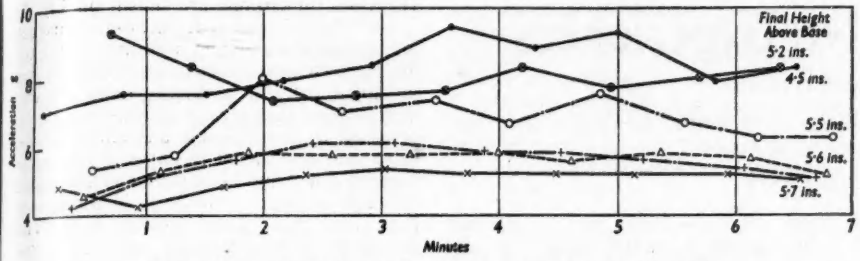


Fig. 4—Acceleration Values for Test Specimen 12in Deep by 12in Wide

mould on the acceleration with constant mix, water cement ratio and mould depth.

(3) The effect of maximum aggregate size on acceleration.

(4) The effect of using an I-section in place of a rectangular section.

In order to reduce the problem to one of two dimensions, the mould was made 3ft in length with a maximum height of 20in and a maximum width of 24in. The mould was constructed of 1in plank suitably battened and lined with hardboard. The ends were drilled and bolted to angles screwed to the sides, thus enabling the sides to be placed at any distance apart, giving variable widths. The various depths were obtained by placing in the required amount of concrete. The coaxial cable from the accelerometers passed through small bore tube which was arranged to support the accelerometers so that they were free to move vertically, but were restrained from tilting out of the horizontal. Any tilting resulted in a reduction in output since the crystals are unidirectional. The layout of junction box, accelerometers and oscillograph is shown in Figs. 2 and 3.

The aluminium alloy bodies of the accelerometers, protected from cement action by a thin layer of grease, were placed in position in the mould and the concrete filled in evenly around them. After completion of the test the concrete was carefully removed and the position of the accelerometers again noted (see Fig. 3). Readings of the oscillograph trace were taken as frequently as possible for each accelerometer in turn, the interval between each reading being of the order of seven seconds. The concrete used was batched dry by weight and mixed in 100 lb lots in a small tilting drum mixer, the mix used for the first two series being 1 : 6 with a 0·45 water cement ratio, the grading being arrived at experimentally to avoid "rotational instability" using aggregates from the Lea Valley.

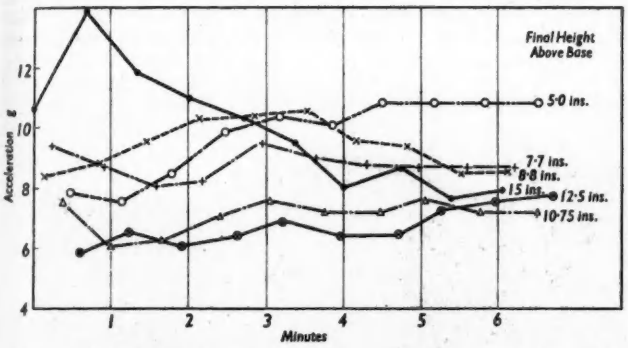


Fig. 5—Acceleration Values for Test Specimen with Concrete Depth of 15½in

The vibrating table, a commercial electromagnetic model running at 3000 c.p.m., was controlled at a given acceleration by means of variable resistances. The acceleration was indicated by a small meter connected to a coil attached to the moving parts of the table and moving between the poles of a permanent magnet mounted on the floor, this meter being calibrated directly in acceleration g. The values obtained, after reduction of the oscillograph readings, were plotted against time for each accelerometer and Figs. 4 and 5 show typical graphs for accelerometers ranged horizontally and vertically in the mould. From these, graphs showing the horizontal or vertical variation of acceleration can be obtained for a given time. Examples of these are shown in Figs. 6 and 7. From Fig. 4 we see that after an initial variation during the first stages of compaction the acceleration at each point approaches a constant value, the variations being attributable to inaccuracies in reading the oscillograph and slight variations in the acceleration of the table. The horizontal curves indicate that Fig. 1 was a fairly good prediction of fact; at mid depth in a vibrating mass of concrete the minimum acceleration occurs at the centre increasing towards the sides.

The vertical curves indicate that for depths of concrete of 8in and 12in the minimum acceleration occurs at mid depth or thereabouts, the acceleration at the surface being greater than at the base, or that of the table, after initial compaction. The curve for the 16in depth shows minimum acceleration at the surface and maximum at two-thirds depth. This was due to the fact that with this depth of concrete behaving as a liquid, the sides flexed slightly under vibration at the same frequency. In all cases the variation of acceleration with depth is gradual.

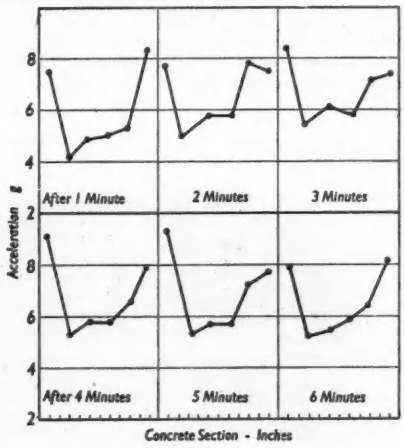


Fig. 7—Acceleration at a Depth of 6in

It will be noted that horizontal and vertical readings do not agree exactly at a depth of 6in and a width of 12in. This is because readings were not obtained simultaneously for vertical and horizontal graphs, also the accuracy of reading the table meter was estimated to be about $\pm\frac{1}{2}g$, so that it was possible to have a slight difference in table acceleration between two tests. Since it is the shape of the curves that are important, and not absolute values, this is immaterial.

From these results it is apparent that there is a considerable reduction in acceleration at the centre of a mass of concrete vibrated from the base, compared with the sides or base. This could mean that when the vibrating unit vibrates with just sufficient acceleration to compact the sides, top and bottom of a casting that the interior would be soft and badly compacted. It is therefore essential that the vibrating equipment for use with precast concrete units larger than a 6in cube should have an acceleration considerably greater than the 2–3g normally accepted as the minimum acceleration to compact a cube.

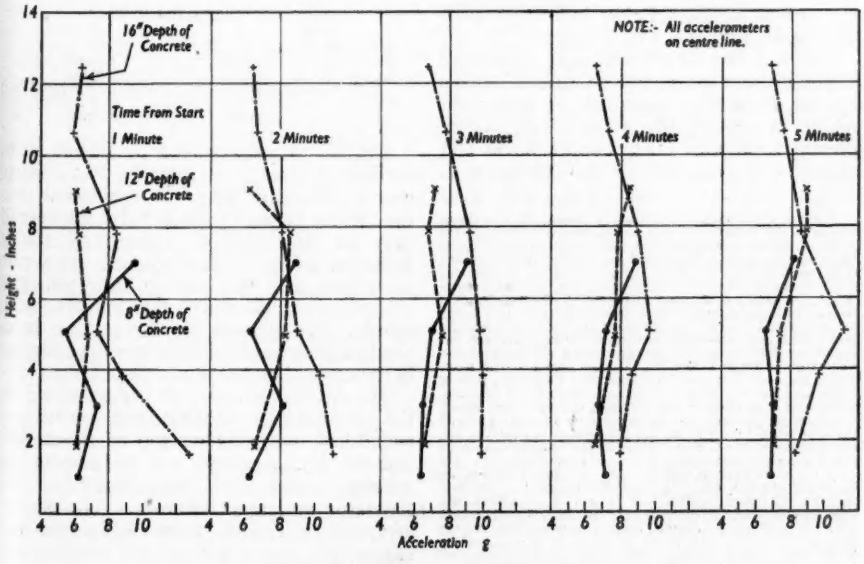


Fig. 6—Acceleration of a Vertical Section

DRILLING FOR NATURAL GAS.—Deep drilling for natural gas has begun at Cousland, near Dalkeith, Midlothian, by the D'Arcy Exploration Company on behalf of the Gas Council as part of the council's five-year search.

French Locomotive Experiences

By EDWARD H. LIVESAY

No. I—"THE GOLDEN ARROW," LONDON/PARIS

(*Continued from page* 272, *February* 19*th*)

PART II—CALAIS/PARIS

IT was mentioned in the first part of this article that, on arrival at Dover, I had been assured by the courteous British Railways official who met me that a corresponding representative of the Société Nationale des Chemins de fer Français—henceforward referred to as the S.N.C.F.—would board the "Invicta" at Calais, take charge, and ease me through the landing formalities, with which I was unacquainted, and so it turned out. I was rushed through everything—literally, even *round* one or two obstacles which affected the *hoi polloi*, but were not allowed to delay me—which was fortunate as time was limited, and "Le Fleche d'Or" waits for no man. I had hoped to have an opportunity to look round the engine before train time, but this proved impossible; only a few minutes were left after arrival alongside the Chapelon "Pacific" at the head of the train, and they were devoted to introductions, sundry officials and the crew being involved. In the last letter from the S.N.C.F. executive in Paris I had been advised that Monsieur Leseigneur, Chief of Traction, Nord Division, would travel with me in the cab from Calais, together with an interpreter. The latter, inspecteur Bernard Fillon, was on hand, but apparently Monsieur Leseigneur was not, or, at any rate, I did not catch his name, so assumed that for some reason or other he had found it impossible to accompany me. This was disappointing, but there was no time to go into the matter, as my attention was distracted by inability to unearth my goggles from a bulging hold-all, and goggles, Monsieur Fillon assured me, were indispensable on a French locomotive.* Thereupon a pair was at once produced by one of the crew and donned. Climbing into the cab—platforms are at rail level in France, as in North America—I was glad to find that it is *de rigueur* to shake hands with the rightful occupants, and show by one's attitude that they are recognised as men and brothers, and that one is a guest in the cab, and not a V.I.P. to whom the crew is expected to defer. As a matter of fact, this has always been my rule, so it was easy enough at once to fall in with the custom of the country, and pleasant to feel the atmosphere was in harmony with my predilections. A snob is out of place in a cab! I am glad to say I always found things pleasant on the footplate throughout the whole tour, without one exception. Invariably I was made to feel at home, and happy—and I hadn't expected to feel either! There were five people in the cab—mecanicien Duterre, chauffeur Morsch, inspecteur Fillon, a second mecanicien† and myself. French cabs are seldom very spacious, and this one was no exception; with five people in it room was at a premium. "Stuffed seats" were conspicuous by their absence—by which I mean there were no seats at all, but this I was prepared for. There are seats on modern classes of engine, but this was a veteran, built in the days before enginemen were pampered—or shaken hands with, I expect! But before we leave Calais a description of the engine (Fig. 3) will be *apropos*.

This was No. 231–E–16, super "Pacific," originally built for the Paris–Orleans Railway by the Fives-Lille Company in 1910, and rebuilt in 1934 by the Ateliers Tours in its present form with Lentz poppet valves and greatly improved steam-flow arrangements. The chief dimensions are shown on Fig. 4.

The "Pacific" type of de Glehn-du Bousquet four-cylinder compound was introduced on the Paris-Orleans Railway in 1907, and ran for some years as originally built. It was then decided that greater efficiency could be obtained by considerable alterations to the valve gear and steam passages at all points between dome and blast pipe, and ultimately the engines assumed the form in which they have since run. Much greater power and economy were obtained; superheat was increased from 572 deg. to 752 deg.; the Kylchap blast pipe (Fig. 5) resulted in reduced exhaust pressure, and economy of fuel was marked.

Referring briefly to some of these features, as Fig. 5 shows, each of the double Kylchap blast pipes has ribs which break the exhaust steam into four jets, giving increased draught with minimum back pressure. The passage from the l.p. valve chests to the blast pipes is, as will be seen from the diagram, very large and direct. Fig. 5 shows a sandbox from which the bogie wheels are sanded to prevent the skidding that was found to take place at certain points, chiefly on curvature. I do not know whether this device is still in use, not looking for it—or knowing about it, to be frank! All sanding is done by air.

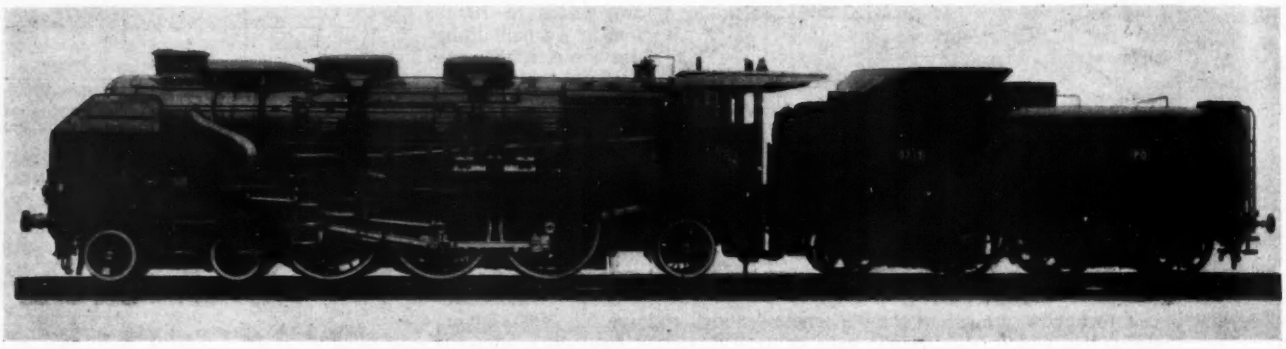


Fig. 3—Super "Pacific" Locomotive, S.N.C.F.

The beneficial results of the adoption of Lentz valve gear are found at all cut-offs, from minimum to maximum. Dimensions and travel are tabulated here:—

Particulars of Lentz Valve Gear

	H.P.		L.P.	
	Admission	Exhaust	Admission	Exhaust
Diameter	7·28in	7·67in	8·66in	9·45in
Maximum travel ...	0·96in	0·94in	1·12in	1·10in

Lift of valves

H.P.		L.P.	
At 13·5 per cent cut-off		At 11 per cent cut-off	
Inlet	6·75mm		5·50mm
Exhaust	19·5mm		24·0mm
At 79·5 per cent cut-off		At 82 per cent cut-off	
Inlet	22·0mm		26·0mm
Exhaust	24·0mm		28·0mm

The valves are actuated by fingers from oscillating cams, and these by Walschaerts gear in the usual way. It was found that the full benefit of the Lentz valve gear could only be obtained by making all steam passages, both live and exhaust, of ample area, and this was one of the principal alterations made when the engines were rebuilt. The two sets of valve gear are independent and can be independently operated in the original de Glehn manner.

The A.C.F.I. feed water heater works on the jet condenser principle, and has its two cylindrical reservoirs on top of the boiler. The first is a condenser and heater—by the exhaust steam—and the second a gas separator and scale remover. The pump, arranged horizontally on the left side of the engine, has two cylinders, one bringing the cold water from the tender into the heater

* He was right, as I soon discovered. A French crew would as soon come on duty without overalls as minus goggles. Goggles should be part of the rig of every engineman and would be if they once realised how valuable and protective they are: a little experience would soon make this clear. In North America they are commonly, though not invariably, worn; in Britain I have very rarely seen them used and after returning from France I made a point of finding out what was the objection. I was surprised to hear from more than one engineman that goggles are actually not allowed! Really, of all the silly, out-of-date rules! The explanation of the interdiction was the risk of lenses being broken by flying objects—presumably coal, or maybe saucers—and eyes injured. Well, well! Is shatter-proof glass unknown in British railway circles? Could not the lenses be made thick enough to be proof against fracture? Do motor-cyclists abjure goggles because of possible injury to their eyes? Eyes are far more likely to suffer from grit and draught than from broken glass in lenses. If French enginemen find them invaluable, and invariably use them, so would their British opposite numbers. *Verb sap.* Finally, I have just thought of a decisive argument: if enginemen are allowed to wear spectacles, and apparently they are, as I have ridden with several wearing them, then why bar goggles?—E. H. L.

† I did not understand the presence of this second mecanicien, though it was appreciated, as I was wearing his goggles; the mystery was not cleared up until the next run, which was to Lille, with the superb "Hudson" No. 232-U1, without doubt the finest locomotive on which I have ever ridden. To this day I cannot even think about it without indulging in mental superlatives. A picture of it hangs on my wall; the memory of it remains with me, and will have to satisfy me for the time being, but only until I can enter its cab again, as I shall do, D.V., this year. After many thousands of miles in the cab I can still feel enthusiasm for locomotives, though not for all locomotives—some I try to forget! But 232-U1—that engine I shall never forget, nor do I wish to—on the contrary. Its beauty, both of design and action; its refinement and completeness of equipment—that is an engine worth travelling on and writing about, and I am glad to have had the opportunity of doing both, all the more when I think of the sad fact—which was news to me, and probably will be to many readers of THE ENGINEER—that the day of the steam locomotive in France is nearing its end. No more are to be built for the S.N.C.F., complete electrification being the ultimate aim. U1 and her sisters, together with the fine Chapelon engines—U1 is not a Chapelon—will have no successors. A depressing thought to anyone "brought up on steam," charm electric, diesel and gas-turbine engines never so wisely. But to return to the mystery: I could clear up "The Problem of the Second Mecanicien" here and now, but to do so would spoil a good story, so the reader must wait for the solution, which will be found in the next article.—E. H. L.

reservoir, and the second forcing the hot water from the separator into the boiler. The employment of this apparatus as a standard fitting on locomotives of the S.N.C.F. is no doubt part of the major aim, economy of fuel, and getting the maximum out of it, so necessary in view of its poor quality, which is never used as an excuse for poor performance. The maximum effort at the drawbar is 34,650 lb with direct admission to all four cylinders, and 28,380 lb working compound. These engines are limited to a maximum speed of 87 m.p.h.

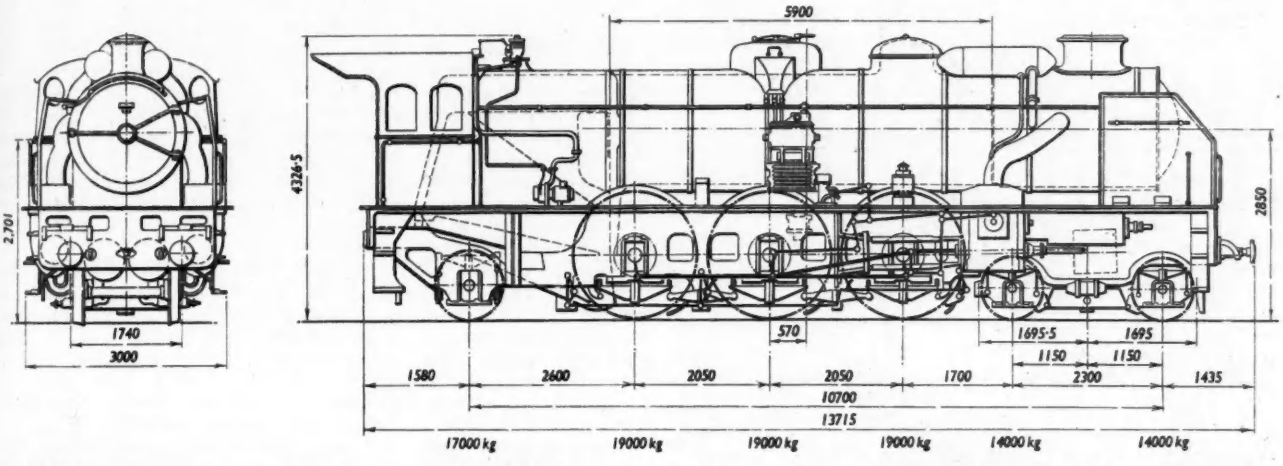
It will be admitted that they are extraordinarily fine machines considering their age—forty-three years—and the fact that they are still—or, at any rate, the ones on which I travelled—in such perfect condition speaks well for the efficiency of the shops in which they are cared for, and, of course, design and material.

"The Golden Arrow," made up of ten coaches, roughly 500 tons net, left Calais Maritime Station at 2.34 p.m., 4 min late; there was no slipping, though h.p. steam was being admitted to all four cylinders. The strong S.W. wind which had raised the white horses I had noticed from "William Shakespeare" nearing Dover, was still blowing broadside on. The gradient, which falls slightly immediately clear of the platform, followed by a kilometre or so of level going, was helpful, to the engine's advantage, but the driving wheels only carry a little over 56 tons, so the factor of adhesion is low and this absence of slipping was interesting. I had rather expected some, in view of these facts, particularly when h.p. working was being indulged in; its non-appearance was typical of the almost entire absence of loss of footing that so impressed me throughout my French experiences—it was uncanny! The regulators must be very easy to work, giving gradual port opening. On many British engines the reverse is the case; drivers have to exert a good deal of energy to open the regulator at all. Sand was used at the start; it is applied to all three pairs of drivers. Acceleration was rapid, despite the negotiation of several level crossings and Calais Town Station. Strange to the engine and its controls as I was, having had no time to look things over before starting, faced by numerous gauges that indicated I knew not what at the moment, besides being positioned on the right—the fireman's—side, it was impossible for me to grasp clearly what was happening in Duterre's corner, or what exactly he was doing. I had rather to let things go, feeling it was inadvisable to be too inquisitive at this early stage, and make myself unpopular by dodging about the cab. Morsch was busy, and I should only have got in his way, so, like Brer Rabbit, I "lay low and sed nuffin'." Operational methods would, no doubt, become clearer in due course, when I consulted Fillon, who was keeping a watchful eye upon the stranger within his gates. He would expound when we became more used to each other and on more familiar terms, which very soon happened.

Left-hand drive is the rule in France, a concomitant of left-hand running, which probably dates back to English influence on French railway construction at its inception, when Britain led the world and other people copied her. I doubt whether France does now or need do so; rather the reverse. A 60km restriction governs the stretch to Calais Station; 5 miles from the start the Caffiers bank begins, 7 miles of 1 in 125 (Fig. 6); it was entered at about 60 m.p.h., the speed falling to 45 m.p.h. at the summit, a little beyond Caffiers Station, and the peak was passed at 2.55, 12m in 21 min. These figures are approximate, as the Flaman recorder, with which—or I suppose the Hasler—all French locomotives are provided, was right in front of Duterre, under the window, and for the time being out of my sight. I cannot say whether reinforced compound working was employed during the ascent—probably not. I have no data of the cut-offs either, but in the light of subsequent experience they were probably about 45 per cent h.p. and 50 to 55 per cent l.p., if reinforced working was not indulged in. If it had been the engine would have slipped, and it didn't.

Down the southern side of the Caffiers bank, 5½ miles of 1 in 125, the speed quickly rose to 70 to 75 m.p.h., which is the "blanket" limitation over most of the distance to Paris; at this rate of travel the riding was noted as "very good." In fact, it was so good, under all conditions, not only on this run, but on the return to Calais on the same type of engine a few weeks later, that it induced speculation. Several details of French and British "Pacific" practice differ, and are probably responsible, with cumulative effect: (1) the springs of the coupled axles are equalised‡; (2) the bogie axles are independently sprung, and the trailing truck is a "Cartazzi," or something similar; (3) the hangers of the trailing springs pass through additional spiral springs, on which they bear; (4) the motion is all as light as possible, and in conjunction with four cylinders, is well balanced; (5) the springs are flat, not cambered; (6) the much greater weight carried by the leading bogie, 27½ tons, followed by the equalised group of coupled axles. But whatever the reason, the "feel" of the engine, and of all the French engines I rode, was quite different to that of the average British machine. It was "springy," shockless; there was nothing harsh or "solid" about it, the engine seemed to be in harmony with the track. In Britain—and I may say in North America, too—they sometimes seem to hate each other! During the whole of my tour, only one of the score or more engines ridden behaved badly—very badly—and that was American; it will be dealt with later.

From Fig. 4 it will be seen that the firebox comes well back into the cab and is of the trapezoidal Belpaire pattern, not the long, narrow type found on some of the earlier Chapelon engines. The distance between shovel-plate and fire-door is less than on British engines, which makes the fireman's work easier, but Morsch was kept busy enough, as the coal was poor stuff, small and dusty; I began to see why goggles are so indispensable on French locomotives. Frequent watering was called for to keep down the dust, so naturally the footplate was rather messy, and Morsch and I soon began to show signs of it, we belonging to the same "part of the ship," to use a



Cylinders (2) h.p., diameter	16½in
Cylinders (2) h.p., stroke	25½in
Cylinders (2) l.p., diam.	25½in
Cylinders (2) l.p., stroke	25½in
Cylinders, ratio h.p. to l.p.	1/2·32
Cylinders, distance between centres, h.p.	7ft 3½in
Cylinders, distance between centres, l.p.	2ft 2½in
Connecting-rod length, h.p.	6ft 10½in
Connecting-rod length, l.p.	5ft 11in
Volume of receiver	10·9 cubic feet

Wheels, bogie, diameter	3ft 2in
Wheels, driving, diameter	6ft 5in
Wheels, trailing, diameter	3ft 10in
Boiler, mean diameter	5ft 6in
Boiler, length between tube-plates	19ft 4in
Boiler, centre from rail	9ft 4in
Steam pressure	246 lb (Hpz. 17)
Firebox (Belpaire)	Trapezoidal, with Nicholson syphon
Firebox, grate area	46·5 square feet
Firebox, width (front)	3ft 3in
Firebox, width (rear)	6ft 2in
Firebox, length	9ft 6in

Heating surface, tubes and flues (inside)	1,797 square feet
Heating surface, firebox	164 square feet
Heating surface, syphon	27 square feet
Heating surface, superheater	784 square feet
Heating surface, total	2,772 square feet
Weight, on bogie	27·5 tons
Weight, driving	56·25 tons
Weight, trailing	16·4 tons
Weight, total	100·15 tons
Tender, wheels, diameter	4ft 1in
Tender, coal	9 tons
Tender, water	7,700 gallons

Fig. 4—Details of Super "Pacific" Locomotive

‡ When the pins and pivots of equalising gear are in good shape the arrangement is worth while; when they are not, it is worse than useless, as weight distribution is upset. This particular engine being French, it can be safely assumed the gear was in good condition!—E. H. L.

Navy term. The other occupants of the cab looked respectable ; we looked like—well, like French firemen—that is the best description I can think of. Subsequent experience led to the conclusion that the average French driver washes his overalls once every six months, whether they need it or not ; the fireman never washes his at all. I am rather in sympathy with this routine ; what is the use of washing overalls—they only get dirty again ! Briquettes were stacked on both sides of the tender, but were not used on this run, nor did I ever see them used during any subsequent trip.§ I was told categorically that they are never used when running, only when the engine is standing in station or yard, or being fired-up—and, presumably, in emergency, so another British misconception goes into the discard. Mechanical axlebox lubricators are on the fireman's side of the footplate, worked off the rear coupling-rod, and the A.C.F.L. lubricator is in full view on the back-plate. This feed-water heater is a standard fitting on French engines, which make use of everything leading to the maximum result being obtained from the poor fuel, but it is only used when the regulator is full open, two Friedman injectors taking care of boiler-feed at other times.

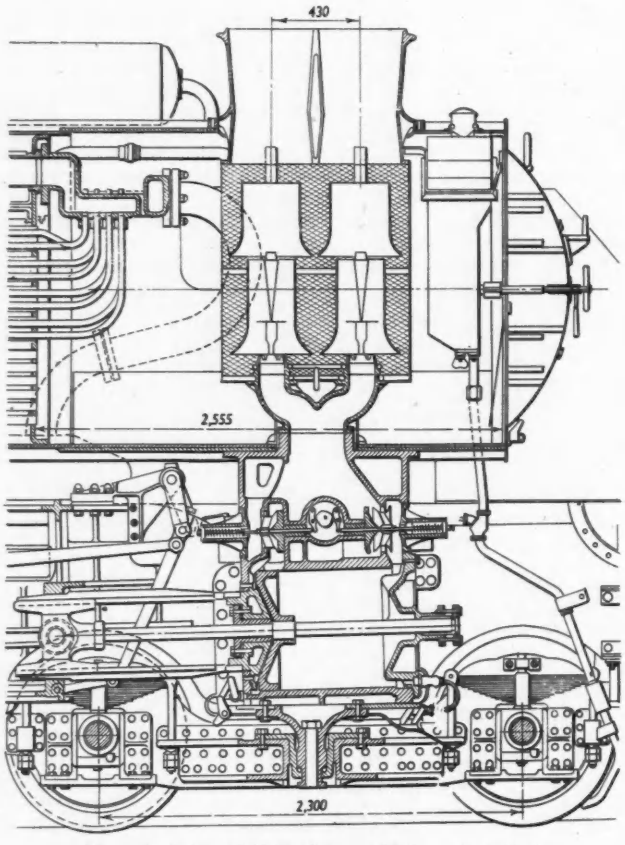


Fig. 5—Cylinder and Valve Gear on the Super "Pacific"

Returning to the running, from the top of the Caffiers bank for 15km, gradients are heavy, both up and down, much being at 1 in 125, which is the ruling figure right to Paris. Boulogne, 26¼ miles from Calais, comes in the middle of a 1 in 125 fall and there is a 50 m.p.h. restriction through the station and over the junction of a spur to the quay. It was passed at 3·08 ; average from Calais 46 m.p.h., over a very heavy stretch, restricted throughout to 75 m.p.h. or less.

§ With one exception—on a 2-8-2 tank engine with a "pull-and-push" train.

I had not yet become *au fait* with the numerous gauges, or able to get close enough to read some of them owing to the density of population in the cab, but I gathered that the regulator was usually about two-thirds open and left there, speed and power variation being done by alteration of travel of the respective h.p. and l.p. valves. In both this was long, the ratio being about 30 per cent or more with the h.p. valves to 50/60 per cent l.p. There were two regulators, held by catch and ratchet, the smaller admitting h.p. steam direct to the l.p. cylinders ; it was only used at starting or for reinforced compound working. The two independent sets of valve gear can be altered separately or locked together and operated as one : generally the latter procedure was followed. Though I wanted to see how Duterre was handling the reverse gear he was rather out of my sphere of observation at this stage of the game. There were too many people in the way for me to break through to his side of the cab ; Fillon, Morsch—generally in vigorous action—and the "second mecanicien." Duterre was evidently a very capable driver, thoroughly at home with the engine. He was a big man with an intelligent, expressive face ; when he said something he was listened to—and obeyed. "This must be one of those specially trained, super-drivers, only to be found on French locomotives," I thought, "the kind we have heard about, who alone are capable of handling these efficient, complicated machines, and getting the best results from them. He does not look to have risen from the ranks ; doubtless he was born like that and then further developed and refined in workshop and technical school until the finished product emerged—a Maestro ! I must watch him." I was impressed even to the extent of being reluctant to ask him anything—via Fillon—lest, Watson-like, I betray myself, and be humiliated by a Holmesian rejoinder, such as "My dear Monsieur Livesay, you have seen my methods—apply them !" No, it was too risky. Better keep quiet until we—he, the engine and myself—were on familiar terms, before consulting the oracle. Tantalising though it was, I should probably gain in the end ; so too will the reader, who must wait a little for the harvest, when we shall all come rejoicing, bringing in the sheaves.

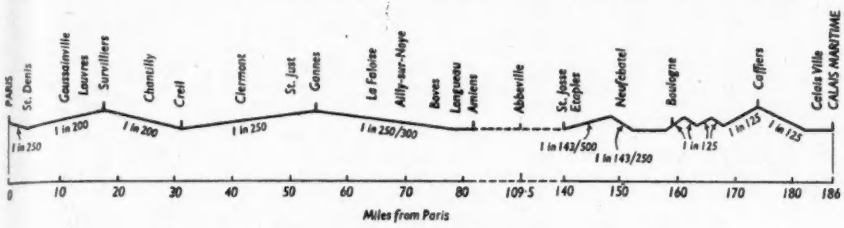
The gauge equipment was very complete ; superheat, receiver pressure, smokebox vacuum, exhaust pressure, all were indicated. Electric light was there, too, switched on in tunnels ; not only in the cab but in front-end indicator lamps. The look-ahead was good and the front windows large, thanks to the more generous French loading gauge—engine height and width are 14ft 3in and 10ft 4in, respectively. Cowls shade the front windows and deflector strips are placed in front of the side ones. The cab, however, was short, and only chains closed the gap between engine and tender, somewhat low-hung ; it would be possible to lose one's balance and capsize over them if one were a trifle top-heavy or outsize. I do not think there was any locker for the crew's personal gear, nor, as already said, were there seats. The strong side wind blowing right through the cab, coupled with the noise of the engine, made conversation with Fillon none too easy ; nevertheless, I could follow everything he said, and his evidently sincere apologies for occasional linguistic lapses were quite unnecessary, as his English was very good ; the care he took to make his enunciation clear and deliberate was charming. I only wished my French had been even fractionally as effective, but the less said about it the better. It merely exasperated me, and probably amused Fillon, though he was far too polite to show it.

Six miles beyond Boulogne there is a stiff climb of 4 miles or so through Neufchatel, mostly 1 in 145, and then down a similar drop to Etaples, passed at 3.26, 1 min early ; the average speed from Calais had risen to 52 m.p.h. Just beyond Etaples marks the end of the really heavy going, as from here right to Paris there are no gradients of any severity. The next 60 miles through Abbeville and Amiens to Longueau show more level track than inclination, and the latter could cause no concern to such an engine as No. 231-E-16. The speed was generally about 75 m.p.h. and again I marked the riding as being very good. Distant signals were audibly indicated in the cab—one blast if "off," two if "on," by means of the usual ramp and shoe. They were acknowledged by push button and marked on the paper strip in the Flaman recorder, but automatic application of the brakes in the absence of acknowledgment does not take place as with the Western Region A.T.C. apparatus.

Abbeville, 76 miles from Calais, was passed at 3.54, 2 min early—average 57 m.p.h. It is nearly level here and for many miles remained so, though with a slight rising tendency ; the speed was still 75 m.p.h., the blanket limit from Calais to Longueau, just beyond Amiens ; the latter important centre was passed at 30 m.p.h.—the local limit is 44 m.p.h.—time, 4.20, 3 min early. So far the run had been perfect, with "The Golden Arrow" on time or slightly ahead throughout ; the overall 75 m.p.h. restriction had never been exceeded, all local limitations were observed, and the first 40 miles had been heavy. The engine's performance, too, had been faultless ; my notebook contains nothing but eulogistic scrawls. It was running like a sewing-machine and riding like a multi-cylinder, well-balanced, well-sprung engine should ride, doing everything I had anticipated from a Chapelon "Pacific." It was delightful to be on an engine in such perfect shape : not an axlebox or big end was knocking, nor side rods clanking ; not a gland was blowing, and in spite of poor coal, steam was always well up and the superheat approximately 700 deg. Yet the engine was built as long ago as 1910 and rebuilt with Chapelon improvements in 1934, so was certainly a veteran which might be excused if it showed signs of senility. There were none that I noticed. As to the value of compounding, while on falling gradients it was obvious from the very low receiver pressure and practically non-existent exhaust that the l.p. cylinders were acting more as counter-pressure brakes than active aids to progress,

that was only to be expected ; when they were needed during a climb they were very much in evidence, though even then the exhaust was far from obtrusive.

Exaggerated claims are often made for these fine " Pacifics "—I do not mean by the S.N.C.F.—by admirers whose enthusiasm does more credit to their hearts than their heads. There is no need for it, as their actual performances are remarkable enough. For instance, I saw it stated recently by an observer—in the train—that when h.p. steam is admitted to the l.p. cylinders a Chapelon " Pacific " can exert a tractive effort of



St. Josse to Amiens approximately level with slightly rising tendency towards Paris.

Fig. 6—Profile, Calais/Paris

50,000 lb. To say the least, this is unlikely ! There being only 57 tons on the driving wheels if it attempted to do anything of the sort it would slip itself to a standstill and exert no tractive effort at all. The statement reminds me of an unfortunate remark made many years ago by an old acquaintance, the well-known motoring pioneer, S. F. Edge, since deceased, who, during a patent action on the validity of the Maybach float-feed carburettor, raised a laugh in court by asserting that a motor in which he was interested " developed 3 b.h.p. under no load." But I digress ; I cannot say what power No. 231-E-16 developed at any point on the run and I am not going to the trouble of working it out by empirical calculation and formulæ. I will leave that to armchair critics, who, not having been there, will no doubt know far more about what actually happened than I, and will be quick to point it out. My task is to set out the facts, on which the reader can form his own conclusions. I have already formed mine without the use of formulæ—they are all favourable !

Nearing and leaving Amiens Station several curves bring a speed limitation to 30 m.p.h. and automatic colour-light signals begin. The track, with flat-bottom rails, looked very well cared for ; the sleepers appeared closer together than in Britain. At Ailly-sur-Noye " The Golden Arrow " was switched on to the down track for 4 miles, to La Faloise, due to relaying work ; temporary signals protected this stretch, over which speed was limited to 40 m.p.h. The result was that at Breteuil, the next station, we were 1 min behind, which was the first time the train had been late since leaving Calais. I noticed that speed variations necessitated by this restriction and the switching from one track to the other were brought about by alterations in the valve travel rather than the regulator, which was hardly touched. On the long 40km easy descent from Gannes through St. Just and Clermont to Creil, it was about half open. Midway, at Avrechy, the 75 m.p.h. speed limit that had governed us right from Calais ended—normally it ends at Boves, just south of Longueau, but the relaying work mentioned had led to its extension to Avrechy—becoming 81 m.p.h. thence to Paris, except for short local restrictions, such as through Creil, where it was 60 m.p.h. Creil is an important railway centre ; the station was run through at 5.16, once more O.T. ; the 154 miles from Calais had been covered in 162 minutes, at 57 m.p.h., though most of the distance had been limited to 75 with several lesser restrictions. I could find no fault with anything *en route* ; mecanicien Duterre had shown commendable virtuosity with his dual controls, which reflected credit on his technical training ; chauffeur Morsch had kept his steam and water just where they should have been and always had a friendly grin for me—especially when I fed him with chocolate. Inspecteur Fillon, my *fidus Achates*, had proved invaluable from the start: he kept a watchful eye on me throughout, and was always ready to lighten my darkness when appealed to, and point out objects of interest *en route*. I resolved to ask for his assistance whenever it was possible for him to accompany me on future runs, and did so. I still apply to him through the mails whenever a Nord point needs elucidation—and never in vain. I had not yet fathomed the presence of the spare mecanicien ; he seemed to have a sort of watching brief, though what exactly he was watching was not apparent—maybe signals—perhaps Duterre was not thoroughly acquainted with the road—I would find out on arrival in Paris.

Among the interesting, because unfamiliar, things noticed in the cab was the fire-door, which was of a type new to me ; it seemed to work admirably. It was hinged at the top, opening inwards, thus acting as a deflector in itself, and being balanced by external weights was very easy to operate. In the event of a burst tube or rush of flame it closes automatically. It was made in three sections, and could be opened in three ways—(1) left and centre, (2) right and centre, and (3) all three together. It is illustrated in Fig. 7. It appeared preferable to the British arrangement, with its toggles and grooves, plus a deflector inside the firebox—which during one of my trips in Britain burned off, falling into the fire, where it made a nuisance of itself throughout the rest of the run. The French arrangement certainly has its points. Another detail : the fire irons are stowed in a cylindrical container on the topside of the bunker, closed by a door, and when required slide forward straight into the firebox. After use they are withdrawn from the fire-door without turning them end-for-end, and slide back into the container, the other occupants of the cab being neither brained nor burned in the passage. " So the fireman has to handle the hot ends ? " Yes, but there is generally a wad of cotton-waste in the cab, a fair insulator ; that is what Jacques uses ! Another little point : once in their receptacle the irons stay there ; they do not slide out when the engine runs down a stiff gradient and jab the fireman in the back, which happened more than once on " Britannia " class " Ariel " between Leeds and Carlisle, I noticed. The fireman was rather annoyed and said so in appropriate terms. Simple, commonsense little things, these, they seemed to me, yet nobody in England appears to have thought of them. I had not even thought of them myself !

After Avrechy, where the 75 m.p.h. restriction ended, the speed rose to the 81 m.p.h. limit, and remained there until checked to 60 m.p.h. through Creil, following which came the 14-mile climb at 1 in 200 up the Survilliers bank, on which it held at 60 m.p.h. or so to the summit. Near the foot, we crossed the high Canardiere viaduct, destroyed by the retreating Germans, and since rebuilt, as apparently have all the many bridges wrecked between Calais and Paris. I noticed little war damage *en route ;* none, in fact, south of Boulogne, but I am not saying there wasn't any ; my attention was so much concentrated on what was happening inside the cab that it is possible external impressions failed to register. Certainly the track appeared sound and well looked after, and there were signs of thoroughness everywhere. Good ballast ; clean, neat, freshly painted stations and signalboxes ; things all seemed in good shape.

Creil, 31 miles from Paris, is a busy junction, and as we slowed somewhat over the points and through the yard I realised the very interesting and pleasant run was nearly over, and was sorry. It is beautiful country here, up the long rise to Survilliers, through the great forest of Chantilly, and as we mounted it at high speed, through the cool evening air, as the shadows lengthened, for once I let my attention stray outside the cab ; cut-off ceased to interest me—Chantilly did. Was it not the French G.H.Q. in the first war ? However, there was little time to day dream ; No. 231–E–16 was holding a steady 60 m.p.h. to the summit, which was passed at 5.33, O.T. There were four tracks

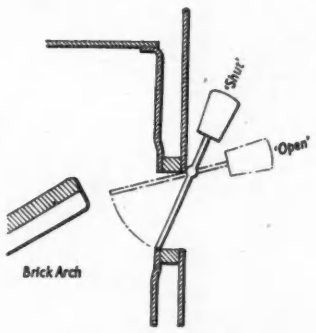


Fig. 7—Firedoor

now, and on the steadily falling gradient on the south side of the ridge the speed again rose to 80 m.p.h., at which it remained until slightly checked at the foot through St. Denis. The four tracks became six, then eight, and the usual signs of approach to a terminus multiplied, and " Le Fleche d'Or " began slowing as it neared the Gare du Nord, coming to a stand in the station at 5.50 p.m., 2 min ahead of time. The 186 miles from Calais had been covered non-stop in 196 min at an average of 57 m.p.h. The run had been very pleasant and instructive, auguring well for the success of the whole tour. Everything had gone so much better than I had anticipated—there had not been the slightest hitch anywhere, and the "human" side of the affair had been delightful. The engine had done its job perfectly, and my companions had been so friendly and helpful that fatigue was never thought of, though I had left London seven hours before, and had been on my feet in two cabs most of the time.

On reaching terra firma, we were greeted by Monsieur Philippe Leroy, of the S.N.C.F., who had ridden in the cab of the " Golden Arrow " from Victoria to Dover the day before. Fillon suggested " *rafraichissement* ";

the word needed no interpretation, and meeting with unanimous approval, we adjourned, just as we were, across the Concourse to a café, leaving the second mecanicien and chauffeur Morsch to look after the engine. Morsch, I noticed, was already going round with cleaning rags, wiping off the motion. Does one ever see that being done in Britain nowadays ? Not in my experience ! " Union rules," I suppose ; such menial, degrading tasks are the business of that almost extinct species, the cleaners. Relaxed, and no doubt satisfied with our respective performances, a very pleasant hour was spent discussing locomotives and associated subjects—Martinis and cool " Pils "—all very grateful and comforting. It was all so novel, different from anything previously experienced in Britain or elsewhere, that the contrast was correspondingly enjoyable. Sitting in the attractive café, looking out at the clean, bustling, orderly station, all three of us bearing grimy evidence of what we had been doing, nobody showed the slightest surprise or objection at our dirty overalls and goggles; the waiter, in fact, was extra attentive. I could not help thinking what would probably have happened in London if we had entered a decent restaurant there in the same condition—supposing we could have found such an oasis within half a mile of the station, which is problematical. Very likely we should have been refused admission, or, if we had succeeded in getting as far as a table, advised to clear out. Ah, but this was France !—they do things differently there ! *Liberté—égalité—fraternité !*—here they were in action ! I was to be given an even greater shock of this kind on the run to Lille with No. 232–U1; it will be touched on in the next article, dealing with this super "Hudson."

During this pleasant stag party, Fillon acting host and interpreter, I was both illuminated and disabused on several points. For instance, the idea generally held in England that French drivers begin their career in the shops, and graduate from there to the regulator without roughening their hands with anything so *infra dig.* as a shovel, turned out to be a delusion. They come up the hard way, from firemen, just as their opposite numbers do in England. That is the rule—it is only the exceptional man, for exceptional reasons, who gets to the left-hand side of the cab in any other way. It so happened that Duterre was one of these exceptional men, and so the rule had not applied to him. I was relieved to hear this, as it showed the instinctive diffidence felt during the run in approaching him, and my appreciation of his obvious ability, had been justified—my judgment had not been at fault. I was also glad to find that the diffidence disappeared in the café, never to return, and that my good judgment was only confirmed on subsequent occasions when we foregathered in the cab. Just how he came to be at the regulator will be explained in the next article, which will also contain the solution of " The Problem of the Second Mecanicien."

But all good things come to an end ; so did this pleasant hour in the café at the Gare du Nord. Still courteous and helpful, my companions guided me to and through the Customs, and found me a taxi, which—unused as I was at this stage to Parisian methods of transport—I had decided to take to Asnieres, my *pied à terre*. Trying to thank them in adequate terms for all they had done, both during the run and since, to make things pleasant and easy for me, and finding difficulty in doing so, I was charmed by Fillon's reply. Speaking deliberately, and evidently choosing his words with care, he said : " Monsieur Livesay, when we met you at Calais, you were a stranger, and our guest—now you are our friend ! " An unexpected compliment, all the more appreciated because I felt he meant it ; it was not merely typical Gallic courtesy. That little incident, too, is not easy to imagine happening in England !

(To be continued)

Gyroscopic Effect of Rotors on the Whirling of Shafts

By J. MANN, M.Sc., A.M.I.Mech.E., and B. B. CLEMENTS, B.Sc.

To calculate the critical speed of a system allowing for the gyroscopic effect by formulæ already established, is laborious and can be invalidated by small errors in the assumed constants of the system. The authors of this article suggest a simplification of the expression given by Morris, 1929, indicate its validity, and deduce the characteristics of several simple systems. Experimental results are given for the case of an overhung rotor, both for positive and negative values of equivalent inertia. These show close agreement with the theoretical. The article concludes with a note on the paper "Transient Whirling of a Rotor," Robertson, 1935, in which the authors show how this analysis can be modified to account for the rotor inertia, and confirm experimentally that the transient always rotates at the critical speed of the system.

AFTER Jeffcott's publication in 1919[1] on the theory of the rotating shaft, several other writers extended the analysis to account for the effects on whirling phenomena of variables such as friction, elastic bearings and the inertia of the system. S. Lees, 1923,[2] published a paper in which he gave a mathematical treatment for a symmetrical overhung rotor of appreciable inertia, and showed that it had only one critical speed, the whirl being driven by the out of balance force due to the slight eccentricity of the rotor, or a slight initial distortion of the shaft.

Since that time the subject has received considerable attention, but there is slight information as to the relative importance of the gyroscopic effect on whirling speeds, in relation to the other variables.

Theoretical Considerations

For a system of given mass, stiffness, &c., the critical speed of rotation may be calculated for different rotor inertias from an expression given by Morris, 1929,[3] and plotted against inertia. Within reasonable limits this gives very nearly a straight line and suggests the following simplification of Morris's formula to a straight line equation.

Nomenclature, Rotor :

I_p lb/sq in = polar moment of inertia.
I_d lb/sq in = moment of inertia about a diameter through the c.g.
I_e lb/sq in = $I_p - I_d$ = rotor equivalent inertia.
$m = w/g$ = mass of rotor, or the equivalent mass of the system.

Stiffness Constants :

y_u in/lb = deflection produced at the c.g. of the rotor by unit load applied there.
z_u in/lb = deflection produced at rotor c.g. by unit couple applied there.
ϕ_u rad/lb in = angular deflection of the tangent to the shaft at the rotor c.g. by unit load applied there.

Speeds : rad./sec :

Ω = critical speed of the system.
$n = \sqrt{1/my_u}$ = fundamental critical speed.
= critical speed neglecting inertia and all other corrections.
$\varepsilon = (\Omega - n)/n$.
$\varepsilon \times 100$ = percentage change in fundamental due to inertia.

The equation derived by Morris for the critical speed is :—

$$m\frac{I_e}{g}\Delta\Omega^4 - \left[\frac{I_e}{g}\phi_u - my_u\right]\Omega^2 - 1 = 0,$$

where

$$\Delta = y_u\phi_u - z_u^2.$$

This can be written

$$A\frac{I_e}{g}\Omega^4 - \left[B\frac{I_e}{g} - C\right]\Omega^2 - 1 = 0,$$

where A, B, C are constants for a given system.

When

$$I_e = 0,\ \Omega = n = \sqrt{1/my_u}.$$

If we write $\Omega = n(1+\varepsilon)$ and substitute

$$\frac{I_e}{g} = \frac{1 - Cn^2(1+\varepsilon)^2}{An^4(1+\varepsilon)^4 - Bn^2(1+\varepsilon)^4}$$

$$= \frac{1 - Cn^2(1+2\varepsilon+\varepsilon^2)}{(An^4 - Bn^2) + (4An^4 - 2Bn^2)\varepsilon + (6An^4 + Bn^2)\varepsilon^2} + \&c.$$

Let

$$a = Cn^2,\ b = \frac{2(2An^2 - B)}{(An^2 - B)},\ c = \frac{6An^2 - B}{(An^2 - B)},$$

substituting,

$$\frac{I_e}{g} = \frac{1 - a - 2a\varepsilon + a\varepsilon^2}{(An^4 - Bn^2)(1 + b\varepsilon + c\varepsilon^2 + \ldots)}.$$

This reduces to

$$\frac{I_e}{g} = \frac{1}{(An^4 - Bn^2)}\{(1-a) - (b - ab + 2a)\varepsilon + [(1-a)(b^2 - c) + a(2b-1)]\varepsilon^2\}$$

Now

$$a = \frac{my_u}{my_u} = 1,\ b = \frac{2\left(\frac{2\Delta}{y_u} - \phi_u\right)}{\frac{\Delta}{y_u} - \phi_u},\ c = \frac{\frac{6\Delta}{y_u} - \phi_u}{\frac{\Delta}{y_u} - \phi_u}.$$

Substituting gives

$$\frac{I_e}{g} = \frac{2\varepsilon}{n^2\left(\phi_u - \frac{\Delta}{y_u}\right)} + \frac{\varepsilon^2}{n^2}\frac{\left(\frac{7\Delta}{y_u} - 3\phi_u\right)}{\left(\frac{\Delta}{y_u} - \phi_u\right)} \quad \ldots (1)$$

If we can ignore the second term in this equation we are left with the linear equation :

$$\frac{I_e}{g} = \frac{2\varepsilon}{n^2\left(\phi_u - \frac{\Delta}{y_u}\right)} = \frac{2\varepsilon}{n^2\frac{z_u^2}{y_u}}$$

as

$$\Delta = y_u\phi_u - z_u^2.$$

Therefore

$$\frac{I_e}{g} = 2\varepsilon m(y_u/z_u)^2 \quad \ldots \ldots \ldots (2)$$

Substituting for ϵ gives

$$\Omega=n\left[\frac{I_e}{2w}\left(\frac{z_u}{y_u}\right)^2+1\right] \quad . \quad . \quad . \quad (3)$$

The above expression has been derived on the assumption that critical speed varies linearly with rotor equivalent inertia. Although this is true for the experimental system described later, it is desirable to investigate the general case to determine the practical limits between which the straight line equation (3) will give correct results for the critical speed.

The easiest approach to this problem is to assume that the limit of validity of the equation is reached when the value for rotor equivalent inertia estimated from the critical speed has a certain permissible maximum error. Thus, if for a particular system the equivalent inertia can be calculated with a certain accuracy, substitution of this value of accuracy will give limits for the rotor dimensions, &c., within which the critical speed will be satisfactorily estimated.

Assuming that the criterion of deviation of the equation from a straight line is a 1 per cent error in the equivalent rotor inertia (this 1 per cent error is chosen arbitrarily for purposes of calculation and may easily be changed to suit the conditions of any particular problem), then referring to equation (1)

$$\frac{I_e}{g}=\frac{2\epsilon}{n^2\left(\phi_u-\frac{\Delta}{y_u}\right)}+\frac{\epsilon^2}{n^2}\frac{\left(\frac{7\Delta}{y_u}-3\phi_u\right)}{\left(\frac{\Delta}{y_u}-\phi_u\right)}.$$

For a 1 per cent error in the equivalent inertia

$$\frac{0{\cdot}01\times 2\epsilon}{n^2\left(\phi_u-\frac{\Delta}{y_u}\right)}=\pm\frac{\epsilon^2}{n^2}\frac{\left(\frac{7\Delta}{y_u}-3\phi_u\right)}{\left(\phi_u-\frac{\Delta}{y^n}\right)}.$$

Consider the positive case.

$$0{\cdot}02=\epsilon(7\Delta/y_u-3\phi_u),$$

substitute for Δ

$$0{\cdot}02=\epsilon(4\phi_u-z_u/y_u^2) \quad . \quad . \quad (4)$$

In the case of a cantilever shaft,

$$y_u=\frac{l^3}{3EI},\ z_u=\frac{l^2}{2EI},\ \phi_u=\frac{l}{EI}.$$

where l, E and I have their standard meaning. Therefore

$$0{\cdot}02=13l\epsilon/4EI.$$

Let $E=30\times 10^6$ lb per square inch, i.e. for steel.

Therefore

$$\epsilon=184{,}500\ I/l \quad . \quad . \quad . \quad (5)$$

Consider the equation (2) :

$$\frac{Ie}{g}=2\epsilon m\left(\frac{y_u}{z_u}\right)^2=\frac{8}{9}\epsilon ml^2.$$

Therefore

$$\epsilon=\frac{Ie}{g}\cdot\frac{9}{8ml^2}.$$

Substitution in (5) gives

$$\frac{Ie}{g}=164{,}000I\ .\ l\ .\ m.$$

Ie/g can be expressed as $m\,.\,f$, where f is some function of the rotor dimensions. Thus :

$$f=164{,}000Il \quad . \quad . \quad . \quad . \quad . \quad (6)$$

By a similar process an expression could be determined for any " pure " system, the general equation being

$$f=\pm KIl,$$

where K is some constant determined from the characteristics of the system. In the case of a system which is not " pure," i.e. the stiffnesses do not bear a simple relationship, equations (2) and (4) must be used.

To illustrate the use of the validity limits the following numerical assessment is given for the experimental system.

For a cylindrical rotor $f=R^2/4-t^2/12$, where R is the radius and t the thickness, thus from equation (6) :

$$R^2/4-t^2/12=\pm 164{,}000Il.$$

The shaft was 0·25in diameter and 10·3in long.

Hence, $R^2/4-t^2/12=\pm 318$.

(*a*) Assume that $t^2/12$ is small in comparison with $R^2/4$ and can be neglected, i.e. a thin disc, then $R=35{\cdot}6$in. Thus, for a thin disc, a diameter of 71·2in must be attained before the straight line equation breaks down.

(*b*) For the negative case $R^2/4-t^2/12=-318$.

Assume that the smallest limit for outside diameter is 1in, hence $t=61{\cdot}7$in. This is impossible as the shaft is 10·3in long. Thus, for all practical purposes the equation is correct to within 1 per cent for the experimental system.

Importance of the Gyroscopic Effect

In the introduction it was stated that as far as the authors were aware, no attempt to assess the importance of the effect in relation to the other variables involved, had been published. The following calculations for three simple systems are given to illustrate the importance of this effect, and give a method by which the characteristics of " pure " systems can be compared.

Consider the following three simple systems :—

(1) Cantilever shaft.
(2) Simply supported De Laval rotor.
(3) De Laval rotor with fixed ends

For comparison let the De Laval rotor be fixed as shown in Fig. 1.

Consider the straight line equation in the form (2).

$$\epsilon=\frac{I_e}{2w}\left(\frac{z_u}{y_u}\right)^2.$$

If it is assumed that there are no corrections to w such as for inertia of the shaft,

$$\epsilon=\frac{f}{2}\left(\frac{z_u}{y_u}\right)^2.$$

Substituting for z_u and y_u for the three systems gives

1. $\epsilon=9f/8l^2$
2. $\epsilon=32f/9l^2$.
3. $\epsilon=8f/l^2$.

If we consider the simple case of a disc rotor $f=R^2/4$, where R is the rotor radius,

Therefore

1. $\epsilon=9(R/l)^2/32$.
2. $\epsilon=8(R/l)^2/9$.
3. $\epsilon=2(R/l)^2$.

Now $\epsilon=(\Omega-n)/n$=increase of the fundamental critical speed due to the gyroscopic effect. Thus a graph of ϵ per cent to the ratio $(R/l)^2$ can be drawn for each system providing, of course, that the validity limits of the straight line equation are not exceeded. This is given in Fig. 1.

This graph shows that the gyroscopic effect can be of great importance in certain cases. For the De Laval rotor with fixed ends the critical speed is doubled if the rotor radius is 0·708 times the length of the shaft. Also for systems where the ratio of the stiffnesses can be simply expressed, the dimensions of the shaft itself make no difference to the gyroscopic effect expressed as a percentage of the fundamental critical speed. The criteria are the ratio of the rotor dimensions to the distance between the bearings, and the rotor position on the shaft. The graph also shows that the cantilever shaft does not produce the greatest gyroscopic effect. A consideration of the deflected shape of the three systems confirms this.

Large values of ϵ may put a particular case beyond the scope of equation (3). In order

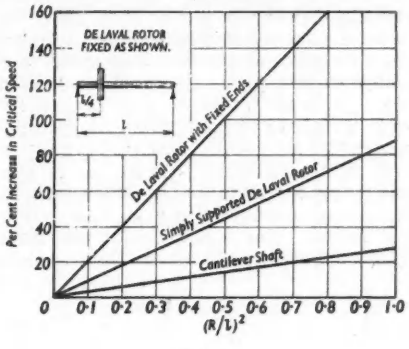


Fig. 1

to expand $(1+b\epsilon+c\epsilon^2+\ldots)$ in the derivation of this equation it was assumed that $(b\epsilon+c\epsilon^2+\ldots)<1$ or alternatively

$$\left(4-\frac{2\phi_u y_u}{z_u^2}\right)\epsilon+\left(6-\frac{5\phi_u y_u}{z_u^2}\right)\epsilon^2+\ldots<1,$$

and this should be checked in cases of doubt.

Experimental Investigation

The drawing of the apparatus given in Fig. 2 shows the general arrangement. The whirling system was composed of a slave cantilever shaft 10·3in long and $\frac{1}{4}$in diameter, with a set of rotors of constant weight (approximately 2 lb), but variable inertia shown in Fig. 3. This shaft was mounted in the headstock of a woodturning lathe and driven by a variable-speed d.c. shunt motor through a four-speed vee belt drive.

The measurement of the whirl amplitude was made by means of a pin head mounted

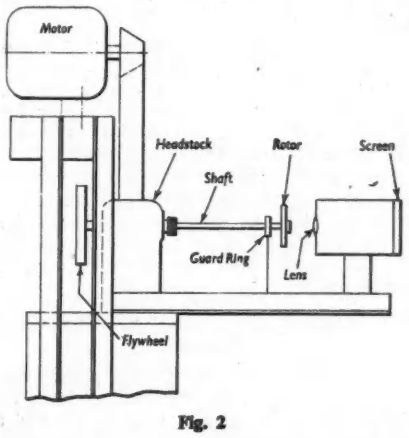


Fig. 2

on the rotor retaining nut, and suitably illuminated at an oblique angle so that it became a point source of light when viewed in the direction of the shaft axis. This light was picked up by a lens and focused on a ground glass screen. Thus when the rotor was whirling a circle of light was traced out on the screen. Measurements of the diameter of this circle gave a comparison of whirl amplitudes.

To estimate the critical speed, a graph of the diameter of the circle was plotted against shaft speed above and below the critical.

A typical experimental curve is shown in Fig. 4 and the critical speed was taken as being midway between the two sections of the graph as shown, there being very little damping in the system. The results obtained experimentally and by calculation are compared in Fig. 5.

It is interesting to note the effect of negative equivalent inertia. The equivalent inertia of a rotor is defined as the difference between the polar moment and the moment about a diameter through the c.g. When the moment about a diameter is greater than the polar moment the equivalent inertia becomes negative and depresses the critical speed, as is illustrated in Fig. 5. This is the case of a long cylindrical rotor or with one of the form of rotor (*g*) Fig. 3, which was specially designed to achieve the maximum depression with the experimental system. It is also interesting to note that it is theoretically possible to construct a rotor of zero equivalent inertia. For a solid cylindrical rotor this would occur when the thickness was $\sqrt{3}$

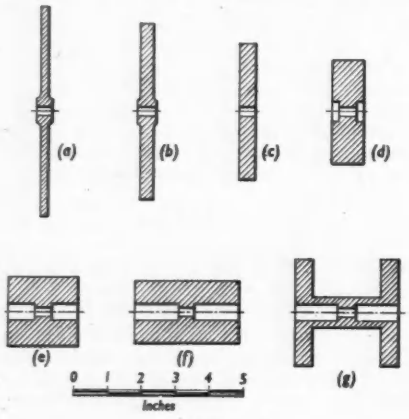


Fig. 3

times the radius. This could be used to eliminate gyroscopic effects in order to investigate other variables in a system.

Conclusions

Although only the simplest systems have been dealt with, the simplified equation forms a powerful analytical approach to problems of a more complicated nature. It expresses the gyroscopic effect as a correction to the fundamental critical speed, and if other variables can be allowed for by similar corrections the estimation of whirling speeds of complex systems will be simplified.

As an example of this approach the authors give the following note to the analysis of the transient whirl as given by Professor D. Robertson, 1935[4] allowing for the inertia of the rotor, and giving experimental corroboration.

The Hysteretically Driven Transient Whirl

During the initial runs of the apparatus the whirl amplitude was observed to hunt at speeds above the critical, causing the whirl amplitude to grow steadily until the shaft struck the guard. This hunting took the form of a waxing and waning circle on the screen, which gradually grew in size. It was realised that this phenomenon fitted the description of a transient whirl as given by Professor D. Robertson, 1935,[4] who describes the transient as a subsidiary whirl rotating about the position of live equilibrium of the normal unbalanced whirl. Thus, as the two whirls get into and out of phase the resultant whirl amplitude waxes and wanes.

In the initial state the hunting was so pronounced and the time of build up of the transient to whirl so short that it was impossible to take any observations of whirl amplitude. Thus it was essential to trace the source of the hysteretic drive of the transient in order to eliminate this undesirable phenomenon, which made it impossible to carry out the tests for which the apparatus was originally built.

A Cambridge torsiograph was used to record the torsional oscillations of the shaft and indicated that the source of the disturbance was in the belt drive and caused by a portion of the belt riding up in a skew manner on the pulley. The torsional oscillations imparted to the shaft were almost eliminated by filing the belt and fitting a flywheel to the shaft. This reduced the time of transient built up to practicable limits. It must be emphasised that the torsional oscillations of the shaft were now very small, but they were still sufficient to drive the transient and cause the shaft to whirl, since the damping was negligible. This work showed that the drive of the transient was dependent upon the magnitude of the torsional oscillations. Robertson, 1935[5] defines hysteretic forces as those which produce friction so as to oppose any change of the shaft deflection, such as the friction which exists at the pins of flexible couplings, and the elastic hysteresis or internal friction of the shaft. In the portion of his paper which deals with elastic hysteresis (the other sources of hysteretic forces were not present in the present apparatus) he showed that when hysteretic forces exist there is an additional force normal to the transient radius and derived an expression to show that if the shaft is running above the critical the net force drives the transient, which thus grows until the shaft is destroyed.

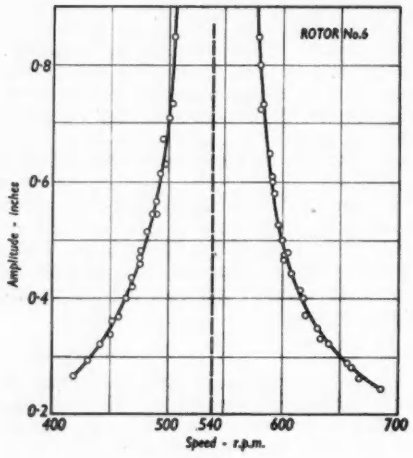


Fig. 4

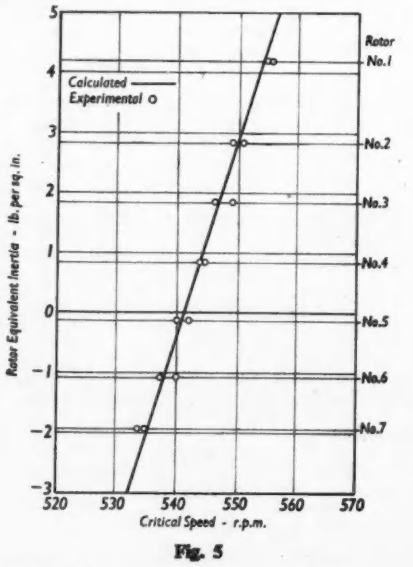


Fig. 5

On the basis of these deductions the explanation of the phenomenon seems to be that each oscillation of the shaft causes a transient to be started, its magnitude being dependent upon the magnitude of the disturbance. This transient is then sustained by the hysteretic forces of the shaft until the next transient is started by the next disturbance of the shaft. Thus each transient will be superimposed upon the previous one and the net effect will be a growth of the radius. The rate of growth of the transient will therefore be dependent upon the magnitude of the oscillations and the hysteretic characteristics of the shaft material and the phenomenon is a special case of the driven transient as discussed by Robertson 1935.[5] It shows that dangerous whirling characteristics can occur in practice with shafts which are subject to torsional oscillations and are running above their critical speed.

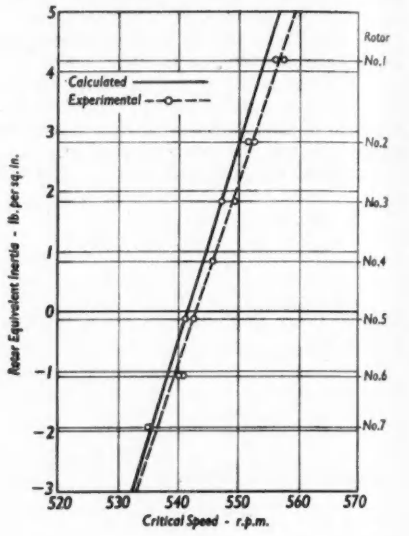


Fig. 6

It has been shown that

$$\Omega = n\left[\frac{I_e}{2W}\left(\frac{z_u}{y_u}\right)^2 + 1\right] \quad . \quad . \quad . \quad (3)$$

Thus for a defined system $\Omega = cn$.

Now $n^2 = 1/my_u$ and for unit mass of rotor $= 1/y_u$. Thus it can be written $\Omega^2 = 1/m'y_u$, where m' is an equivalent mass and $m' = m/c^2$.

The use of m' as an equivalent mass is legitimate as $I_e/2W$ can be written $f/2$, where f is some function of the rotor dimensions and z_u/y_u is some constant times the length of the shaft (i.e. for a cantilever $3/2l$). Thus the mass of the system can be modified in Robertson's calculation, 1935[4] to show that the transient whirl always rotates at the critical speed, taking into account rotor inertia. This has been experimentally verified for the seven rotors (Fig. 3), using similar methods to those employed by Robertson.[4] The results are compared with the calculated critical speeds in Fig. 6. These show a good agreement with the theory, but show a slight tendency for the transient to rotate at a higher speed than calculated for large values of equivalent inertia. The authors feel that this may be due to experimental errors, but think that a discrepancy of some importance may become evident with very large gyroscopic effects.

The conclusions reached are that the

transient whirl always rotates at the critical speed of the system within the experimental accuracy attained, and thus indicates a possible method of experimental determination of the critical speeds of systems by forced torsional oscillation of the whole system.

The experimental work described in this article was carried out in the laboratories of the Engineering Department of the University of Nottingham, and the authors would like to express their appreciation of the facilities granted by Professor J. A. Pope.

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Southern Region Change of Frequency Scheme

A comprehensive scheme is in hand for change of power supply frequency on the suburban system of the Southern Region, British Railways. Completion of the scheme will mean the end of conversion from 25 c/s and all power supplies will then be taken from the British Electricity Authority at 50 c/s. The scheme, which is outlined here, is estimated to cost about £11,500,000. It involves the provision of seventy-one remotely controlled rectifier substations, seventy track paralleling installations, seven switching stations for 33kV circuits, and three new points of connection to the existing 33kV, 50 c/s substations.

LAST Friday, at the invitation of the Southern Region, British Railways, we were able to see something of the progress that has been made in the scheme for change-over of power supply frequency from 25 c/s to 50 c/s on the whole of the Southern suburban system. When the scheme is complete all the power supplies will be obtained at 50 c/s from the British Electricity Authority. It will be recalled that the history of the change-over is closely linked with the history of electric traction on the suburban lines of what is now the Southern Region of British Railways. As a result of the 1923 grouping the technical differences between the existing component systems were resolved by standardising on the third rail d.c. system at 600V, since raised to 660V.

By 1930 the suburban electrification had as its outer terminals Gravesend, Orpington, Bromley North, Hayes, Addiscombe, Caterham, Tattenham Corner, Epsom Downs, Dorking, Chessington South, Guildford (via Effingham Junction), Hampton Court, Shepperton, and Windsor. The d.c. supply was obtained from forty-nine manually operated rotary converter substations fed at 11kV, three phase, 25 c/s. On the Western Section power was generated at the railway's own Durnsford Road Power House, whilst on the Central and Eastern Sections power was received from the London Electric Supply Corporation's Deptford power station, which was originally built for the supply to the railway only.

These substations and power stations are now at the end of their economic life, the Deptford power station having meanwhile been extended and reconstructed for 50 c/s. In addition, the load has increased because of the number of electric trains added by the outer area electrifications which have always been supplied at 50 c/s independently. A further increase in load is expected later this year; ten-car trains will be substituted for the present eight-car trains on certain routes on the Eastern Section. Provision is also required to meet increased power demands for extension of services, and it was therefore decided to replace the whole of the 25 c/s power distribution system with a new 50 c/s system employing remotely controlled rectifier substations at a cost of about £11,500,000, of which £1,750,000 is allocated to civil engineering works. The scheme provides for seventy-one substations, together with seventy track paralleling hut equipments, seven switching stations for 33kV circuits and three additional points of connection to the existing 33kV, 50 c/s fed substations. All the substations will be operated by supervisory remote control from one of the three new control rooms. The substations are arranged so that the track voltage can be increased from 660V to 750V at some future date. Implementing of the scheme will result in better average track voltage with consequent improved lighting of electric trains, reduced line losses and increased protection against track short circuits. There will also be provision for future increases of the train services.

All the power for the new 50 c/s system is obtained from the British Electricity Authority. Four supply points are fed from Deptford generating station at 66kV over three-core, 0·25 square inch, oil-filled feeder cables, terminating in three single-core, fluted lead, 0·25 square inch, oil-filled cables. These 66kV feeders connect Deptford generating station separately to 45MVA transformers adjacent to railway substations at Nunhead, South Bermondsey, Lewisham and Brockley. Other supply points from the British Electricity Authority are at 33kV and are taken over the Commission's three-core, 0·25 square inch, oil-filled cables from the British Electricity Authority's grid substations at Northfleet (two feeders), Wimbledon (five feeders) and Leatherhead (two feeders), and from their Croydon "B" generating station (two feeders, one of which was installed in advance of the change-of-frequency scheme). From these supply points the feeders are taken to a railway substation and thence distributed to the other substations. In addition, connection is made at Walton, Guildford, Egham, Leatherhead, Purley, South Croydon, and Chislehurst with the 33kV system already installed by the Southern Railway for its outer area electrification scheme.

Fig. 1—Nunhead Substation Showing 45MVA, 66/33kV Transformer Equipment with Existing Substation Building Adapted for Rectifiers

Cable System

All 66kV and 33kV feeder cables are accompanied throughout by a multi-core star-quad pilot cable which carries the circuits for the "Solkor" feeder protection and supervisory remote control as well as the low-oil-pressure indication for the oil-filled feeder cable, telephones, electric clocks and metering. The h.v. cables are paper-insulated, oil-filled, lead-alloy-sheathed and served (with an impervious layer in the serving) and are not armoured. The pilot cables are armoured, and the number of cores in the pilot varies between twelve and seventy-six cores. Generally the feeder cable, with its pilot, is laid in surface reinforced concrete troughing without sand or other filling, and is covered with a reinforced concrete lid. Where there are two feeder cables, one pilot cable usually suffices, and the concrete troughing is divided into two compartments; the smaller one takes one feeder cable and the larger takes the other as well as the common pilot. The oil-filled cables are continuously supported and, where they are carried over bridges, along parapet walls or under viaducts they are placed in asbestos cement tubes supported by steel hangers. Where the ground is suitable the cables are laid direct in the ground at a depth of about 1ft 6in and protected with a reinforced concrete slab laid on the surface above each cable. The cables are manufactured and laid by Pirelli-General Cable Works, Ltd. The total length of feeder cable on the whole scheme is about 300 miles. Cable laying started in August, 1952, and approximately 100 miles of cables have already been laid and jointed.

Main Transformers

From Deptford power station the 66kV supply is taken directly to outdoor 66/33kV, 45MVA transformers at Nunhead (Fig. 1), South Bermondsey, Lewisham and Brockley. The first two are supplied by the British Electric Transformer Company, Ltd., and the others by the Hackbridge and Hewittic Electric Company, Ltd. All are to the same specification and the equipment at each consists of one three-phase, 45MVA transformer, star connected on the 66kV side, with on-load tap-changing equipment in eleven 1½ per cent steps to give normal or up to 4½ per cent increase or down to 10½ per cent decrease in ratio. On the 33kV side the transformer is delta connected and with a separate star-connected earthing transformer, the secondary of which provides 130kVA for oil pumps and auxiliary circuits. The neutral point of the earthing transformer is earthed through a convector type liquid neutral-earthing resistance

Fig. 2—33kV Switchgear in Queens Road Substation

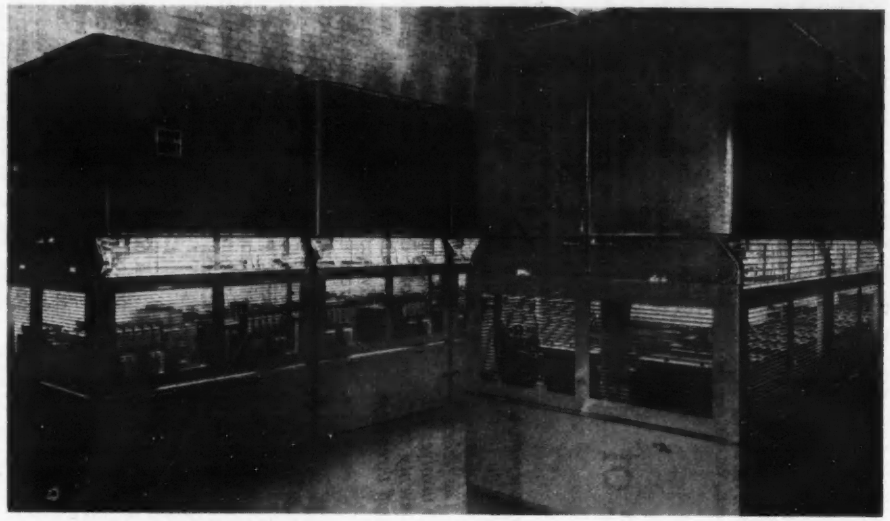

Fig. 3—Glass-Bulb-Rectifier Cubicles in Queens Road Substation

Fig. 4—D.C. Switchgear in Queens Road Substation

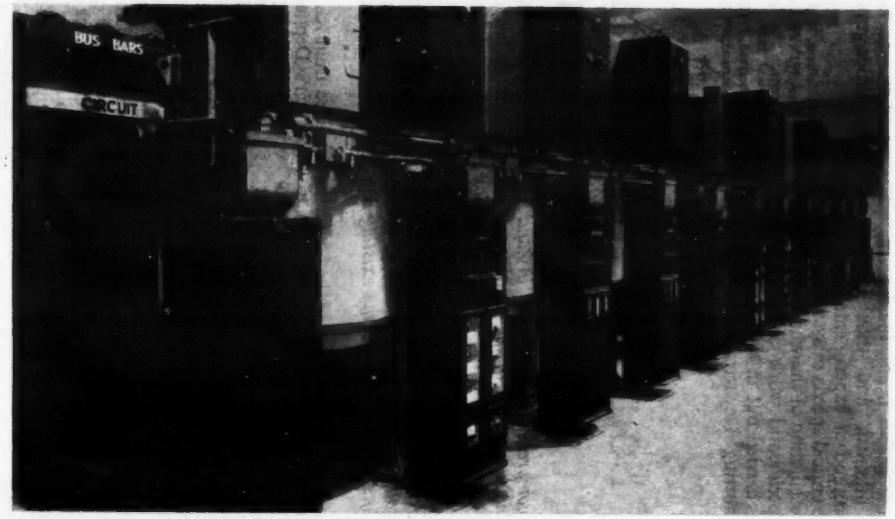

Fig. 5—33kV Switchgear in Lewisham Switching Station

supplied by the British Thomson-Houston Company, Ltd., and is so arranged as to pass 788A for thirty seconds with a current transformer connected between the transformer neutral and the resistor. Both the main and earthing transformers are equipped with Buchholz protection, the main transformer being cooled by external coolers, through which the oil is pumped. The 66kV feeder is terminated in single-core sealing ends on the outdoor structure from which bare copper connections are taken direct to the transformer bushings. The 33kV connections are similarly arranged, with two three-phase circuits in parallel, of 0·4 square inch single-core screened

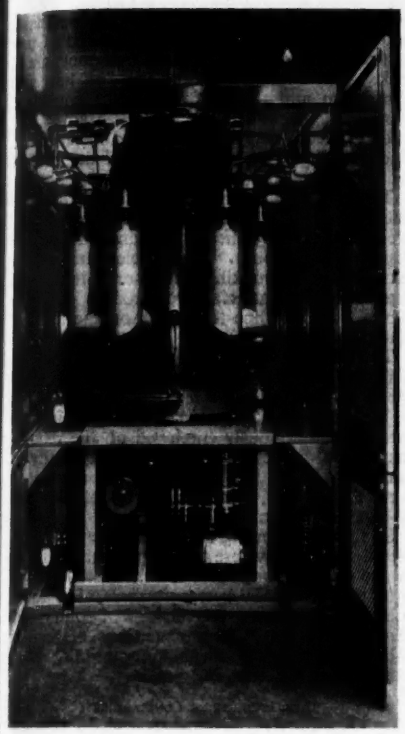

Fig. 6—Six-Anode Pumpless Steel Tank Rectifier on Withdrawal Truck

solid type cables from sealing ends on the structure to the switchgear in the substation. The 66kV cables, the transformer and the 33kV cables are protected by "Solkor" overall protection arranged to trip both the 66kV oil circuit breaker at Deptford generating station and the 33kV oil circuit breaker at the substation. At Nunhead, South Bermondsey and Brockley the 33kV switch (with the switches on outgoing feeders and transformer connections) is placed in the adjacent substation, but at Lewisham it has been necessary to build an independent switchhouse (Fig. 5), as space in the substation is not yet available.

Substation Equipments

All the substation equipments are to the same specification and contain from one to five pumpless air-cooled mercury arc rectifier equipments, each rated at 2500kW continuous output on the d.c. side at 750V. The rectifier transformers are all of O.N. outdoor design and are delta connected on the primary (33kV) side with an externally operated tapping switch to give normal or plus or minus 2½ per cent or 5 per cent voltage correction and with internal links to allow the output of the rectifier to be 660V or 750V. When operating at 660V the full-load d.c. output is 2200kW. The transformer secondaries are arranged in twelve-phase zigzag connections. A tertiary winding is provided for operating the rectifier cooling fans and auxiliary circuits. Full-load output current of the rectifier set is 3333A at either 660V or 750V, according to the tapping connected on the transformer primary.

The h.v. switchgear is of indoor metalclad single busbar design with withdrawable oil circuit breakers having a rupturing capacity of 750MVA. A withdrawable 10kVA auxiliary transformer with a three-phase four-wire output of 415/230V is provided on certain feeder units arranged to plug into the feeder side of the unit. The oil-filled three-core feeder cables are brought to stop joints outside the substations and the feeders continue as three-core screened solid type cables to terminal boxes on the back of the switchgear. The connections between the h.v. switchgear and the main transformer also take the form of three-core screened solid type cable.

The d.c. switchgear consists of truck-mounted high-speed circuit breakers with a continuous rating of 3000A for the feeders and of 5000A for the rectifiers. The trucks for the high-speed circuit breakers are 2ft wide. The feeder circuit breakers are arranged to trip on forward current, whilst the rectifier circuit breakers are arranged to trip on reverse current. Overload protection of the rectifiers is provided by inverse definite minimum time overcurrent relays and by instantaneous overcurrent relays, all mounted on the h.v. switchgear. Instantaneous earth leakage relays are also mounted on the h.v. switchgear for the protection of the rectifier transformer.

The substation contracts have been allocated in three groups. On the western section the h.v. switchgear consists of "KSB7" equipment (Fig. 2), supplied by The General Electric Company, Ltd.. The contractor for the rectifiers and transformers is the Hackbridge and Hewittic Electric Company, Ltd., which is providing glass bulb three-anode rectifiers—a rectifier set consisting of seven cubicles (Fig. 3), each containing four glass bulbs, giving twenty-eight bulbs per set. The four glass bulbs of each cubicle are connected as a twelve-phase set. Cooling is provided by a variable-speed fan installed immediately below the bulbs, the fan speed being a function of the load on the rectifier. As can be seen from Fig. 3, the rectifiers can be dismantled without the use of heavy handling gear; the upper half of each cubicle is split on the longitudinal axis. The contractor for the d.c. switchgear (Fig. 4) and for the d.c. switchgear in the track paralleling huts on this section is Bertram Thomas (Engineers), Ltd. The feeder high-speed circuit breakers are calibrated for a range of overcurrent settings from 5000A to 10,000A. They are latched in and are not provided with a hold-on coil. They incorporate a relay to reduce the trip value in sympathy with a drop in voltage, to the extent that if the track voltage falls to 40 per cent the circuit breaker will trip on zero current. This is a useful characteristic, for it makes the circuit breaker more sensitive to track faults.

A 110V switch-closing and tripping battery, with combined metal rectifier trickle and quick-charging equipment, and a 50V battery with similar charging for operation of the supervisory control are supplied by Chloride Batteries, Ltd.

On the central section The General Electric Company, Ltd., is supplying the same kind of h.v. switchgear as on the western section. This firm is also supplying the transformers and rectifiers. The rectifiers are six-anode, pumpless, air-cooled steel cylinder units (Fig. 6), four cylinders forming a 2500kW set and arranged in two twin cubicle assemblies, each twin cubicle forming a twelve-phase assembly. The d.c. switchgear in both substations and track paralleling huts is supplied by the British Thomson-Houston Company, Ltd., and consists of truck-mounted high-speed "RJR" circuit breakers. In this case two high-speed circuit breakers in parallel are arranged to form the rectifier circuit breaker and, although mechanically independent, they are arranged electrically to operate as one unit. The circuit breakers have hold-on coils energised from the track supply so that a falling voltage trip characteristic is obtained inherently at a value dependent on the overcurrent setting of the breaker. The feeder high-speed circuit breakers are calibrated for a range of overcurrent settings from 5000A to 10,000A. The battery equipments are supplied by Chloride Batteries, Ltd.

On the eastern section the h.v. switchgear is supplied by the British Thomson-Houston Company, Ltd., and is of the "MF.36" metalclad design (Fig. 5). The transformers (Fig. 7) and rectifier equipments are supplied by the English Electric Company, Ltd. The rectifiers are six-anode air-cooled, sealed, steel tank units, arranged in pairs on each side of a central gangway, each pair being a twelve-phase assembly. The d.c. switchgear in the substations and track paralleling huts is supplied by the British Thomson-Houston Company, Ltd., and the battery equipments by Pritchett and Gold and E.P.S. Company, Ltd., are similar to those for the other two sections.

Centralised Remote Control

Supervisory remote control equipment is being supplied by The General Electric Company, Ltd., and has been specially adapted to give very rapid operation and indication, rendered necessary by the very large number of rectifier and feeder equipments controlled from each control station. There will be three control stations (at Raynes Park, Selhurst and Lewisham), and these areas of control have been made to agree very closely with the railway operating areas on the Western, Central and Eastern Sections so far as they come within the boundaries of the scheme. Twenty-eight substations will be controlled from Raynes Park, seventeen from Selhurst and twenty-six from Lewisham; 33kV switching stations, supply points and track paralleling huts will come in the area of each control centre. Certain substations have their equipment divided between two control stations so that a method of alternative control from either of two control stations is employed for certain important substations in the inner area. This provision applies, for example, to Queens Road substation, which will be controllable alternatively from Selhurst or Raynes Park.

Fig. 7—Rectifier Transformers and Cable Ways at Hither Green Substation

Substation Buildings

Of the seventy-one substations, forty-five are in new standardised buildings (Figs. 7 and 8). Two are in viaduct arches and twenty-four are in buildings (Fig. 1, for example) which were pre-

viously occupied by the 25-cycle rotary converters. These are to be converted for accommodation of the rectifier equipment. A further three of these buildings are being used as 33kV switching stations and will also contain track paralleling d.c. circuit breakers. Of the original forty-nine rotary converter substations, four were replaced by 50 c/s rectifier equipment before or during the war, the equipment of one substation being used to provide an extra substation on the inner area and the rest being distributed amongst other substations. Forty-six substations therefore remained in service at the start of the present scheme, so that nineteen substation buildings are released for other purposes.

The standard substation building is to a common basic design, but slight variations are made to adapt this design to the requirements of the equipment for the three areas. It consists mainly of a rectifier room and a switchgear room, a partition wall separating the two, with swing door access between them. A battery room and a lavatory are built into the switchgear room, but with external access only. The buildings have 15½in cavity outer walls, the external width being 28ft 1in. They are placed longitudinally parallel with the track. The transformer is positioned outside the rectifier room between the building and the track. The d.c. switchgear in service until the new is commissioned or to provide temporary switchgear in a temporary hut.

Track paralleling huts are to a standard design, except for three buildings to accommodate shelf-mounted circuit breakers released from elsewhere. The only variable is the length of the building.

The complete scheme is being designed and carried out to the requirements of the chief officer (electrical engineering), British Transport Commission. The installation of the cable, substation and supervisory control equipment is being executed under the supervision of the electrical engineering (new works and development section), British Transport Commission, in consultation with the mechanical and electrical engineer, Southern Region, who has also been responsible for the production of the low-voltage feeders and track switching equipment.

Various phases of the work involved in the change of frequency scheme were seen during our tour of various sites last Friday. At New Eltham we saw a new substation building which is nearing completion ready for the installation of electrical equipment. A substation in a much more advanced stage was to be seen at Hither Green (Fig. 7), where the transformers, rectifiers, switchgear and cabling are already installed.

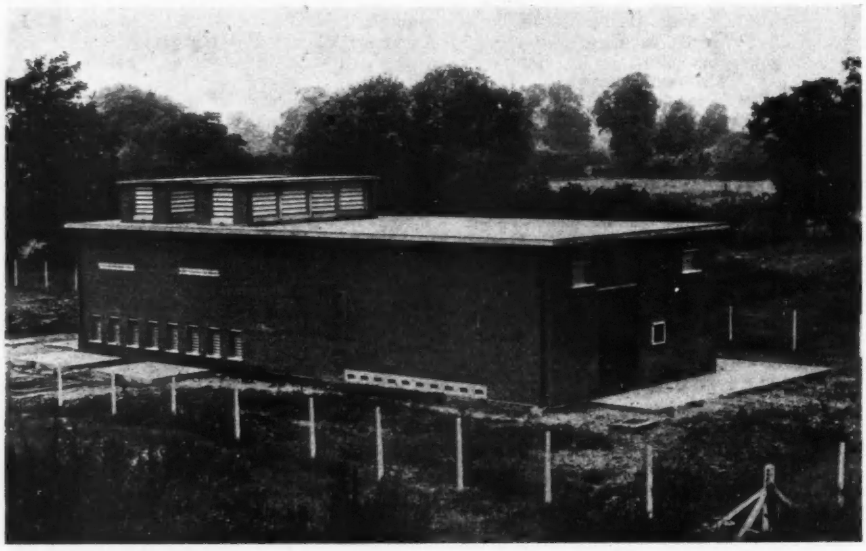

Fig. 8—Berrylands Substation Building Completed Ready for Electrical Installation. The Transformer Bases and Cable Entries are on the Left and the Concrete Entry Blocks for Positive and Negative D.C. Cables are on the Right

d.c. switchgear is placed against the wall of the switchgear room nearer to the track, and the h.v. switchgear is placed close to the back wall opposite the d.c. switchgear. A draw-out space common to h.v. and d.c. switchgear separates the two. The basic design is flexible in length to allow of the rectifier room taking one or two equipments, and of the switchgear room taking the number of h.v. or d.c. switch units required at each site. Where more than two 2500kW rectifier equipments are required at a substation (as, for example, at Queens Road), two separate buildings are provided, being arranged left- and right-handed to allow up to four 2500kW rectifier equipments. An interesting aspect of the design of all these buildings is the complete elimination of trenches and the use of a suspended trunking system for small wiring interconnections, &c., as shown in Fig. 2 (top left) and Fig. 4.

Two substations are being built in arches. One of these substations (Blackfriars) will occupy two arches and contain two rectifiers, and the other (Bermondsey) will occupy seven arches and contain five rectifiers after the removal of existing rotary converters.

The conversion scheme is complicated in certain cases by the necessity of keeping some of the rotary converters in service in the substation until an equivalent plant capacity of new rectifiers can be commissioned in it. It is sometimes necessary, for instance, either to keep the old

Later, at Queens Road, we saw a substation in operation; this substation is arranged in two sections, "A" and "B," and part of the rectifier installation in one section is illustrated in Fig. 3. During our visit we also saw a new track paralleling hut at New Cross Gate; a 66kV supply point and converter substation at Lewisham, where the scheme involves the replacement of rotary converters by rectifier equipment in the existing building; and another 66kV supply point at Nunhead, where the rectifier substation is being housed in the existing building (Fig. 1).

Civil Engineering Work

The work differs from pre-war extensions of electrification in that it is being carried out on an existing electrified system and in the most congested area of the Southern Region. Unlike most new works involving heavy expenditure, the civil engineering work here consists of a large number of relatively small jobs (the largest not costing more than about £50,000) spread over an area of some 500 square miles. In a number of cases it has been necessary to provide reinforced concrete rafts, piled foundations, reinforced concrete sub-structures or heavy retaining walls.

The new buildings are being constructed to standard designs, typical examples of which are shown in Figs. 7 and 8. As the result of past experience on the Region, it was decided that all buildings should be constructed with cavity brick walls, in the case of substations 15½in thick, and in the case of track paralleling huts 11in thick. The interior brickwork is flush pointed and painted with two coats of cream emulsion paint. The roofs consist of reinforced concrete beams and slabs cast-in-situ, waterproofed with ¾in asphalt laid in two layers and painted internally with two coats of white emulsion paint. The roofs of track paralleling huts consist of a concrete slab cast-in-situ and waterproofed with three-ply bituminous felt. The concrete floors are finished with granolithic paving, 1½in. thick, which is subsequently painted with a special concrete paint to improve the appearance and also to prevent dusting.

Concrete cable entry blocks, roof ventilator units, lintels and sills are manufactured of pre-cast concrete or artificial stone. All doors are of teak. The wall ventilators are of hardened aluminium and the roof ventilators consist of asbestos louvres secured in teak frames with internal aluminium alloy expanded metal grilles. The buildings generally have been designed to reduce maintenance costs to the minimum.

The low-voltage cable route work and the alterations to conductor rails, track bonding, &c., are being done by the civil engineer employing departmental labour. The cables are laid in surface wooden trunking, but at some sites special supporting structures are required to carry the cables from one line to another on the faces of viaducts or bridges.

The concrete troughing for the high-voltage and supervisory cable routes is being made by the civil engineer at the regional concrete works at Exmouth Junction, where some thirty-five men are continuously employed on the requirements of this scheme. The total quantity of concrete used in this troughing will amount to some 55,000 tons, incorporating about 2000 tons of steel reinforcement.

So far the following buildings have been completed to a stage where they can be handed over to the electrical engineers for the installation of equipment:—45MVA transformer rafts, four; substations, fifteen; conversions of rotary converter substations, one; extensions of rectifier substations, three; switching stations, two; track paralleling huts, forty-one.

Civil Engineering Contractors

The following list shows the contractors for the civil engineering work:—

Erection of substations and track paralleling huts: Tersons, Ltd., Demolition and Construction Company, Ltd., J. W. Ellingham, Ltd., L. and W. Whitehead, Ltd., James Longley and Co., Ltd.; erection of control stations: Trollope and Colls, Ltd., W. H. Gaze and Sons, Ltd.; excavations: J. E. Wallis and Sons, J. B. Edwards and Co., Ltd., Aubrey Watson, Ltd.; provision of pre-cast concrete and artificial stone units for substations and track paralleling huts, Girling's Ferro Concrete Company, Ltd., Cooper Wettern and Co., Ltd.; piling to foundations, Piling and Construction Company, Ltd.

Books of Reference

The Electrical Trades Directory: The Electrical Journal Blue Book, 1954. London: Benn Brothers, Ltd., Bouverie House, Fleet Street, E.C.4. Price £2 10s.—There are more than 61,000 references in the seventy-second edition (1954) of this directory to the electrical and allied industries. Many sections of the book have been enlarged. Details are given of about 7000 manufacturers and some 6000 other firms, including engineers (arranged in twenty-seven categories), installation contractors, wholesalers and distributors, importers and exporters, agents and patent agents. In the largest section of the book—that devoted to products and materials—there are 40,000 references, set out under 2100 headings. Some 500 new entries have been made in the Trade Names section, which now contains more than 5000 names. The directory also contains useful information about the British Electricity Authority, its Generation Divisions, main power stations and Area Boards; Government departments and research establishments; British Railways and London Transport; the Institution of Electrical Engineers and other professional and trade organisations associated with the electrical industry. Prominent people in the industry are listed in the Personal section of the directory.

Work Study Conference.—A conference on work study and planning applied to plant maintenance is being arranged by the Society of Industrial Engineers. It will be held at Roffey Park, Horsham, Sussex, from April 9th to 11th, the subjects to be considered including planning and organisation of work, method study, work measurement and incentives. The fee for each member of the conference is six guineas, which includes accommodation, and full particulars may be obtained from the Education Officer of the Society of Industrial Engineers, 28, Victoria Street, London, S.W.1.

Structural Approach to Aeroelastic Problems*

By D. WILLIAMS, D.Sc., M.I.Mech.E., F.R.Ae.S.†

In this paper the author discusses the impact which the electronic digital computing machine can exercise on the whole field of structural analysis. As the method of successive approximations as carried out by such a machine makes the use of matrix notation necessary, sufficient of the elementary properties of matrices is explained. In the first part of the paper reproduced herewith two forms of the equations of motion for a deformable elastic system are derived and converted into matrix form. The successive iteration process for obtaining modes and frequencies is then explained and the whole process is illustrated by examples. The second part of the paper (not reproduced here) shows how the method is applied to the complex structure of a delta wing.

It is a truism to say that no problem in aeroelasticity can be solved without first deriving the elastic characteristics of the structure concerned. In some problems, such as that of determining the critical speed for reversal of aileron control, the elastic properties of the structure under static loads are all that are required in so far as the structure itself is concerned. In most other problems, however, it is necessary to know, in addition, the distribution of mass over the structure—in other words, its inertial properties. With these two fundamental properties fully defined, it is then possible to calculate the vibrational characteristics of the structure, i.e. its natural frequencies and modes. Having found these, or been presented with them, the aeroelastitian needs to know nothing further concerning the structural properties of the aeroplane, his main task thereafter being to derive its response to aerodynamic forces.

In this lecture I propose to discuss only the structural side of the aeroelastic problem, and endeavour to indicate how radically it is being affected by the advent of the electronic digital computing machine—hereafter usually referred to as " the machine."

Although the main theme of this lecture is the profound impact of the electronic digital computing machine on the structural approach to aeroelastic problems, it is my view that the impact on structural analysis—or " stressing " as it is commonly called—is going to be no less profound. For it is obvious that, if the response of a structure to applied loads can be determined accurately enough to form the basis for computing a whole series of frequencies and modes, that same response, giving as it does deflections in terms of loads, constitutes a valuable help towards, if not indeed everything that is required for, stressing the structure. As this is true for every kind of structure used in mechanical and civil engineering, the change which the machine can bring about in man-hours of computation can only be described as revolutionary.

I should here explain that my main object is to expound the general principles of the new approach rather than try to describe or compare the various detailed procedures that are now coming into use. It will be gathered from this that, in preparing this lecture, I have had chiefly in mind the ordinary structural engineer and not the few specialists in this field.

The lecture divides itself naturally into two parts. The first part, by general argument and by a simple example worked out longhand, shows the kind of operations carried out by the machine. And for the reason that the machine likes its data to be provided in the form of matrices, and also that the matrix notation is rapidly becoming the " lingua franca " in the field of aeroelasticity, I have tried to indicate the potentialities of the matrix approach for coping with the kind of problem we are here concerned with.

The second part is intended to show how the principles established in the first part are applied to actual aeroplane structures.

Calculation and Scale Model.—There are two main methods of ascertaining the elastic behaviour of an aeroplane before it is built, one is by calculation and the other is by model experiment. There is nothing to prevent both methods from being adopted for solving the same problem, so making the results obtained by the one method a valuable check on the other. A model good enough to provide reliable values for the lowest half-dozen frequencies and modes cannot be built in much under six months, but, once built, it can be used at once for flutter experiments in the tunnel. Changes in mass distribution can also be made very easily and their effect on the flutter characteristics observed directly. Thus, however attractive the approach to aeroelastic problems via machine computation may appear, the approach via a simplified model is not to be lightly set aside. I shall, however, make no further reference in this lecture to the approach via scale models.

It is impracticable, because of the heterogeneous character of this structure to write down, the general equation of motion of an aeroplane structure leading, as such an equation should, to a solution containing an infinite number of natural frequencies and modes. Recourse is therefore had to the universal device of representing the actual structure by one possessing only a limited number of degrees of freedom. The greater the number of the degrees of freedom, the more nearly will the motion of the hypothetical structure conform to that of the actual structure, and it is here that the digital computing machine scores so heavily. Whereas 6 degrees or 8 degrees of freedom were in the past considered an ambitious number to aim at, the use of five to ten times that number is now becoming common with machine help. It has to be remembered that the computational work goes up somewhat more rapidly than the cube of the number of degrees of freedom, to appreciate the advance that this represents.

Parameters for Defining Structural Displacement.—The parameters in terms of which the displacement of the structure is defined are commonly chosen in one of two ways. These are well illustrated by the simple case of the cantilever beam, the displacement shape of which can be represented either by the independent displacements of a set of points along the beam, as shown in Fig. 1(*a*) or by some combination of the curves (three only shown) of Fig. 1(*b*) defined by the ratios of their amplitudes. It is generally accepted that, for maximum accuracy from a given number of degrees of freedom, the second method holds the advantage. This is natural when it is considered that, with 1 deg. of freedom alone allowed, it is still possible for the true displacement shape to be given accurately by a single curve of (*a*), but impossible by the displacement of a single one of the points in (*b*) to the exclusion of displacement at any of the others.

When, however, it is not imperative to restrict the number of degrees of freedom there is everything to be said for the straightforward simplicity of defining the elastic deformation in terms of the displacements of an adequate number of individual points. The method has the further advantage, which is generally recognised, of being more suitable for application to complex structures like the delta wing, and particularly

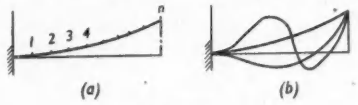

Fig. 1

to structures in which the mass distribution is uneven. Moreover, it is admirably suited to the process of deriving the elastic characteristics of a complete structure like a wing from those of its individual elements—a process that will presently be described.

Use of Matrix Methods

The method of successive approximations as carried out by the " machine " requires that the sequence of operations it is asked to perform should be completely regimented. For this purpose the matrix notation is highly suitable, and therefore a casual acquaintance with that notation is desirable for understanding how the work is partitioned between man and machine. As most structural engineers are unacquainted with matrix work, I propose to describe the very few properties of matrices that need to be known for appreciating their use in the new scheme of things.

The Two Forms of the Equations of Motion.—The two forms in which the equations of motion of a deformable elastic system can be written

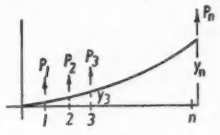

Fig. 2

are well illustrated by the variable section cantilever, whose behaviour under static loading may be considered first.

Fig. 2 shows such a cantilever divided into n sections by n stations 1, 2, 3.....n, with the actual mass distribution represented as nearly as possible by n discrete masses, m_1, m_2.....m_n, whose displacements are denoted by y_1, y_2.....y_n.

In the static problem the inertia forces are irrelevant, so forces P_1, P_2.....P_n acting at the n stations are assumed. The internal energy U can now be expressed in two ways :

(i) In terms of the deflections y alone, or (ii) in terms of the forces P alone.

The first gives an expression

$$U_y=\tfrac{1}{2}(a_{11}y_1^2+a_{12}y_2^2+\ldots+a_{nn}y_n^2)+\\+(a_{12}y_1y_2+\ldots a_{rs}y_ry_s+\ldots) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

and the second gives

$$U_P=\tfrac{1}{2}(b_{11}P_1^2+b_{12}P_2^2+\ldots+b_{nn}P_n^2)+\\+(b_{12}P_1P_2+\ldots b_{rs}P_rP_s+\ldots) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

These are homogeneous quadratic functions of y and P respectively (in which, since we assume that deflections vary linearly with load, the reciprocal relations $a_{rs}=a_{sr}$, $b_{rs}=b_{sr}$ hold). According to Castigliano's First Thorem,

$$\partial U_y/\partial y_r=P_r \quad . \quad . \quad . \quad . \quad . \quad (3)$$

and according to his Second Theorem,

$$\partial U_p/\partial P_r=y_r \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

—two partial differential equations.

Equation (3) is true for non-linear load-deflection relations as well as linear, but equation (4) is true only for linear systems. As, however, all deflections are assumed to be directly proportional to load either (3) or (4) can be used.

By giving r successive values from 1 to n we

Notation.

y_r—Vertical deflections normal to wing at station r, either total or due only to elastic deformation—according to sense.
P_r—Static force at station r (also used for fin reactions).
U_y—Strain energy in terms of deflections y.
U_P—Strain energy in terms of static forces P.
a_{rs}—" Stiffness " coefficient = force at station r due to unit displacement at station s with zero displacement maintained at every other station.
b_{rs}—" Influence " or " flexibility " coefficient = deflection at station r due to unit force at station s, with zero force at every other station.
ϕ—Circular frequency of vibration.
A_r—Amplitude of vibration of displacement y_r at station r.
$A_r^{(n)}$—Value of A_r in n^{th} vibration mode.
m_r—Effective mass at station r.
$g_{rs}=b_{rs}m_s$.
l—Distance of a station from a datum line.
l_f—Distance of fin from reference base.
K—Constraining moment per radian displacement.
φ—Angle of roll of reference base.
δ—Deflection of spars and ribs relative to a sloping base, also elastic deflections of fin normal to its plane.
α—Slope of spar or rib relative to a datum line, also used for fin rotation about its base.
F_r—Vertical reaction at station r due to deformation of structure.
y'_r—Displacement at station r directly due to freeing reference triangle.
θ—Angle of pitch of reference triangle about own base.
A^0_r—Arbitrary initial value of A_r in iteration process.
ψ—Angle of yaw of reference base.
A'_r—Maximum amplitude of y'_r.
z_r—Displacement of fin at station r normal to plane of fin.
z_0—Lateral displacement of mid point of base of reference triangle.
h_r—Height of fin station r above fixing base.
h_f—Width of fuselage at base of fin.
f_{rs}—Local influence coefficients for fin deflection relative to *encastre* fin root.
j_{rs}—Stiffness coefficient for fin stations corresponding to influence coefficients f_{rs}.
q_r—Distance of wing station r from plane of symmetry.
B_r—Maximum total amplitude of z_r.
H—Width of reference base triangle.
B'_r—Amplitude of z_r directly due to freeing base triangle.
M—Mass of wing and fuselage (minus fin).
T_r—Yawing moment of inertia of wing and fuselage about mid point of base of reference triangle.
a_{fr}—Stiffness coefficients for fuselage station 7 due to fin lateral forces.
C_r—Constants derived from the summation of products.

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* " Recent Developments in the Structural Approach to Aeroelastic Problems," Royal Aeronautical Society, February 11th. Abstracts.

† Royal Aircraft Establishment.

obtain n equations from (3), which are best visualised in the expanded form

$$\left.\begin{aligned} P_1 &= a_{11}y_1+a_{12}y_2+\ldots\ldots+a_{1n}y_n \\ P_2 &= a_{21}y_1+a_{22}y_2+\ldots\ldots+a_{2n}y_n \\ &\ldots\ldots\ldots\ldots\ldots\ldots \\ P_n &= a_{n1}y_1+a_{n2}y_2+\ldots\ldots+a_{nn}y_n \end{aligned}\right\} \quad . \quad . \quad (5)$$

In the same way equation (4) gives

$$\left.\begin{aligned} y_1 &= b_{11}P_1+b_{12}P_2+\ldots\ldots+b_{1n}P_n \\ y_2 &= b_{21}P_1+b_{22}P_2+\ldots\ldots+b_{2n}P_n \\ &\ldots\ldots\ldots\ldots\ldots\ldots \\ y_n &= b_{n1}P_1+b_{n2}P_2+\ldots\ldots+b_{nn}P_n \end{aligned}\right\} \quad . \quad . \quad (6)$$

Although one set gives loads in terms of deflections and the other deflections in terms of loads, each set fully defines the elastic characteristics of the cantilever. Indeed, each set can be solved to give the other. It is to be noted, however, that it is more straightforward and more accurate to obtain U_P than U_y, for the reason that the latter involves the second differential of the displacement y, and for other reasons, and therefore it is sometimes better to derive equation (5) by the inversion of (6) rather than directly from U_y.

Equations in Matrix Form.—The matrix method of approach may be illustrated right here, both in the matter of notation and use. Thus equation (5) can be written in the form

$$\begin{bmatrix} a_{11}a_{12}\ldots\ldots a_{1n} \\ a_{21}a_{22}\ldots\ldots a_{2n} \\ \ldots\ldots\ldots \\ \ldots\ldots\ldots \\ a_{n1}a_{n2}\ldots\ldots a_{nn} \end{bmatrix} \begin{bmatrix} y_1 \\ y_2 \\ \ldots \\ \ldots \\ y_n \end{bmatrix} = \begin{bmatrix} P_1 \\ P_2 \\ \ldots \\ \ldots \\ P_n \end{bmatrix} \quad . \quad (5a)$$

and the way to read this is self-explanatory. The successive terms in the first row of the n-sided square matrix of stiffness coefficients a on the left multiply the successive y terms in the adjacent column matrix of y's, the sum of the products being equated to the topmost term in the R.H.S. column matrix of P's. This gives the first equation in (5); the second and successive equations of (5) are given by repeating the process with the second and successive rows of the square matrix. In matrix jargon, what has been done in (5a) is to "pre-multiply" a column matrix (the y column) by a square matrix to give another column matrix (the P column).

If there were two columns of variables in the multiplied matrix—the existing y column and a new x column—the y column would be pre-multiplied by the square matrix exactly as before to give the same P column, upon which the same pre-multiplication of the x column would introduce a new P column on the R.H.S. of (5), which would thus become a two-column matrix. It follows at once that an n-columned matrix of variables pre-multiplied by the n-sided square matrix would give n columns on the R.H.S., i.e. an n-sided square matrix of P's. In other words, the product of two n-sided square matrices is another n-sided square matrix.

So much for matrix notation. The usefulness of the matrix method is equally well illustrated by reference to the two sets of equations (5) and (6). Putting (6) in matrix form,

$$\begin{bmatrix} b_{11}b_{12}\ldots\ldots b_{1n} \\ b_{21}b_{22}\ldots\ldots b_{2n} \\ \ldots\ldots\ldots \\ \ldots\ldots\ldots \\ b_{n1}b_{n2}\ldots\ldots b_{nn} \end{bmatrix} \begin{bmatrix} P_1 \\ P_2 \\ \ldots \\ \ldots \\ P_n \end{bmatrix} = \begin{bmatrix} y_1 \\ y_2 \\ \ldots \\ \ldots \\ y_n \end{bmatrix} \quad . \quad (6a)$$

where the square matrix of flexibility coefficients b is called a flexibility matrix just as the square matrix of stiffness coefficients a in (5a) is called a stiffness matrix.

As already stated, when equation (5) is solved for the y's the block of "a" coefficients is concerted into the block of "b" coefficients of equation (6). The parallel operation in the two matrix equations (5a) and (6a) is to invert the square matrix of a's into the square matrix of b's. The process is called "inversion" by simple analogy with the equation

$$ay=P \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

which has the alternative form

$$y=a^{-1}P \quad . \quad . \quad . \quad . \quad . \quad (7a)$$

Thus, if $[a]$ represents the "a" matrix and $[b]$ the "b" matrix, $[a]^{-1}=[b]$. Now the important point is that a simple routine manipulation of the a matrix will invert it to give the b matrix, and the process can be done by the machine.

For the purpose of the lecture this is practically all that need be borne in mind regarding matrix notation and operation. Multiplication has been illustrated in detail, but inversion only in what it does—the process itself need not be discussed here.

Natural Modes and Frequencies.—When the cantilever is vibrating in one of its natural modes at frequency ω, every point on the beam performs a simple harmonic motion, so that

$$y_r=A_r \sin \omega t \quad . \quad . \quad . \quad . \quad (8)$$

and at full amplitude, if m_r is the associated mass, the inertia force

$$P_r=m_r\omega^2A_r \quad . \quad . \quad . \quad . \quad (9)$$

By using (8) and (9) equations (5) and (6) are at once converted into equations of motion which take the form respectively of (10) and (11):

$$\left.\begin{aligned} m_1A_1\omega^2 &= a_{11}A_1+a_{12}A_2+\ldots\ldots+a_{1n}A_n \\ m_2A_2\omega^2 &= a_{21}A_1+a_{22}A_2+\ldots\ldots+a_{2n}A_n \\ &\ldots\ldots\ldots\ldots\ldots\ldots \\ m_nA_n\omega^2 &= a_{n1}A_1+a_{n2}A_2+\ldots\ldots+a_{nn}A_n \end{aligned}\right\} \quad (10)$$

$$\left.\begin{aligned} A_1 &= b_{11}(m_1\omega^2A_1)+b_{12}(m_2\omega^2A_2)+\ldots\ldots+b_{1n}(m_n\omega^2A_n) \\ A_2 &= b_{21}(m_1\omega^2A_1)+b_{22}(m_2\omega^2A_2)+\ldots\ldots+b_{2n}(m_n\omega^2A_n) \\ &\ldots\ldots\ldots\ldots\ldots\ldots \\ A_n &= b_{n1}(m_1\omega^2A_1)+b_{n2}(m_2\omega^2A_2)+\ldots\ldots+b_{nn}(m_n\omega^2A_n) \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

By dividing (11) throughout by ω^2 we obtain

$$\left.\begin{aligned} \frac{1}{\omega^2}A_1 &= (b_{11}m_1)A_1+(b_{12}m_2)A_2+\ldots\ldots+(b_{1n}m_n)A_n \\ \frac{1}{\omega^2}A_2 &= (b_{21}m_1)A_1+(b_{22}m_2)A_2+\ldots\ldots+(b_{2n}m_n)A_n \\ &\ldots\ldots\ldots\ldots\ldots\ldots \\ \frac{1}{\omega^2}A_n &= (b_{n1}m_1)A_1+(b_{n2}m_2)A_2+\ldots\ldots+(b_{nn}m_n)A_n \end{aligned}\right\}$$

. . . . . (11a)

or, in matrix form,

$$\frac{1}{\omega^2}\begin{bmatrix} A_1 \\ A_2 \\ \ldots \\ \ldots \\ A_n \end{bmatrix} = \begin{bmatrix} b_{11}m_1b_{12}m_2\ldots\ldots b_{1n}m_n \\ b_{21}m_1b_{22}m_2\ldots\ldots b_{2n}m_n \\ \ldots\ldots\ldots \\ \ldots\ldots\ldots \\ b_{n1}m_1b_{n2}m_2\ldots\ldots b_{nn}m_n \end{bmatrix} \begin{bmatrix} A_1 \\ A_2 \\ \ldots \\ \ldots \\ A_n \end{bmatrix}$$

. . . . . (11b)

in which the square block of coefficients (bm) is called the "dynamical matrix."

"Successive Iteration" Process for Obtaining Modes and Frequencies

Where the machine scores is that, apart from the capacity to multiply and invert matrices, it can carry out long iterative processes in astonishingly fast times, and my purpose next is to indicate what it does in this respect (not, however, how it does it).

An equation like (10), treated in ordinary analytical fashion, leads to the usual determinantal frequency equation of power n in ω^2, the $(n-1)$ ratios between the A's being then found for each root ω^2 to give the mode for that frequency. It has long been known, however, that equations of type (10) and (11a) can be solved by successive iteration. Taking equation (11a), for example, one guesses a particular mode by giving arbitrary values to the n amplitudes of vibration $A_1\ldots\ldots A_n$, and, for convenience, giving A_n the value of unity, since the ratios of the A's are alone of interest. If the same value of $1/\omega^2$ satisfied all n equations in (11a) we should have guessed right.

As it is, the value of $1/\omega^2$ given by the last equation of the set can be taken as a first approximation. On now dividing the quantities obtained on the L.H.S. of the remaining $(n-1)$ equations (obtained from the guessed first set of A's on the R.H.S.) by the value of the first approximation to $1/\omega^2$ just obtained, a new set of A's is derived, in which A_n is still unity. The process is then repeated until finally a value of $1/\omega^2$ and a corresponding set of amplitudes A are found that satisfy all the equations. The whole value of this process of iteration rests on the fact that the successive values of $1/\omega^2$ converge steadily and fairly rapidly towards the correct value (except when two frequencies happen to lie rather close together, when it becomes necessary to make some adjustment to the process in order to hurry the convergence). Once that correct value is reached further iterations obviously merely repeat that value, and when the machine does the iterating the operator can see at once when that stage is reached and sets it going on the next harmonic.

It can be shown by a simple proof that this first value of the root $1/\omega^2$ is at the same time its highest value. In other words, by this method the lowest or fundamental natural frequency is obtained first. If the set of equation (10) had been used (after dividing through by the m's) the highest value of the frequency would hvae been arrived at first, a fact that makes it essential to express the elastic characteristics of a structure in terms of a set of deflection (or influence) coefficients—the flexibility matrix—rather than a set of stiffness coefficients, or stiffness matrix. Where, for any reason, it is convenient to derive the stiffness matrix first, its inversion must precede the iterative process.

Higher Modes and Frequencies.—Having found the fundamental mode as a set of n amplitudes $A_1^{(1)}$, $A_2^{(1)}\ldots\ldots A^{(1)}{}_{n-1}$, 1 (the superscript 1 referring to the first mode), the next higher mode is derived by using the fact that the inertia forces m_1A_1, $\ldots\ldots m_nA_n$ associated with a set of amplitudes in any remaining mode do no work in operating over the fundamental set—a direct consequence of the orthogonality of the modes. Thus,

$$(m_1A_1)A_1^{(1)}+(m_2A_2)A_2^{(1)}+\ldots+(m_{n-1}A_{n-1})A^{(1)}{}_{n-1}+ +(m_nA_n)1=0 \quad . \quad . \quad . \quad . \quad (12)$$

an equation which establishes a relation between the amplitudes A of any vibration from which the fundamental mode has been excluded, or "swept out."

It enables one of the A's (say, A_1) to be expressed in terms of the others and so to reduce the number of degrees of freedom by unity. In (11a), therefore, we can omit the first equation and so, by substituting the value of A_1 given by (12) in the remaining $(n-1)$ equations, be in a position to derive by iteration the highest remaining frequencies together with its associated mode, $A_2^{(2)}$, $A_3^{(2)}$, $\ldots\ldots A_n^{(2)}$. The value $A_1^{(2)}$ of A_1 in the second mode is given, of course, by (12) (the superscript (2) denoting the second mode).

In like fashion, every remaining mode will be orthogonal, both to the first and second modes, and therefore will satisfy not only (12) but also the relation

$$(m_1A_1)A_1^{(2)}+(m_2A_2)A_2^{(2)}+\ldots+(m_nA_n)A_n^{(2)}=0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

By using (12) and (13) to express A_1 and A_2 in terms of A_3, A_4, ... A_n in any remaining mode we can dispense with the first two equations of (11a) and write the remaining $(n-2)$ equations in terms of A_3, A_4, $\ldots A_n$. Iteration of this set gives the third mode $A_3^{(3)}$, $A_4^{(3)}$, ... $A_n^{(3)}$ with $A_n^{(3)}$ and $A_2^{(3)}$ then found via (12) and (13).

Matrix Method of Iteration.—The advantage of the matrix notation is that it enables the iterations just described to be systematised—a great help to the desk computer, but a *sine qua non* to the machine. Just as equation (6) gave the matrix equation (6a) so does equation (11a) give the matrix equation (14):

$$\begin{bmatrix} g_{11}\ g_{12}\ldots\ldots g_{1n} \\ g_{21}\ g_{22}\ldots\ldots g_{2n} \\ \ldots\ldots\ldots\ldots \\ g_{n1}\ g_{n2}\ldots\ldots g_{nn} \end{bmatrix} \begin{bmatrix} A_1 \\ A^2 \\ \ldots \\ A_n \end{bmatrix} = \begin{bmatrix} A_1 \\ A_2 \\ \ldots \\ A_n \end{bmatrix} 1/\omega^2$$

. . . . . (14)

where, for conciseness, coefficients g_{11}, g_{12} and so on have been written for $b_{11}m_1$, $b_{12}m_2$ and so on in the square dynamical matrix.

The easiest way to see how the process of matrix iteration works is to consider a very simple example, which can also serve to show how the dynamical matrix itself is formed.

Fig. 3 shows a uniform beam $C'C$, whose evenly distributed mass is represented by six equal discrete masses m, pitched a distance l

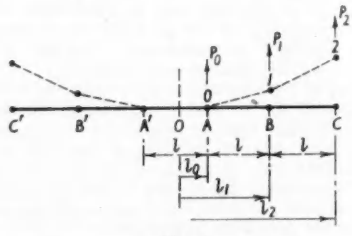

Fig. 3

apart at C^1, B^1, A^1, A, B, C. The elastic stiffness of the beam is represented by sprung hinges at the mass stations, each hinge applying a constraining moment $k\theta$ for any angular displacement θ between adjacent segments.

The Symmetrical Case.—Consider the symmetrical vibrations of the free-free beam, in which by definition the middle segment A^1A remains horizontal, but is free to move up and down. By symmetry, only the right-hand side of the beam need be considered.

First, derive the flexibility coefficients b of equation (6), either by first writing down the internal energy U_P, and then differentiating with respect to the P's, or directly by the usual and more practical method of writing down the deflections at all stations (here referred to as stations 0, 1 and 2) due to the application of unit load at each station in turn.

Taking OA (which remains horizontal) as a datum, a unit load is applied at station 1 and the deflections obtained at 1 and 2, i.e. b_{11} and b_{21}, as $(1\times l)/K\times l$ and $(1\times l)/K\times 2l$, or l^2/K and $2l^2/K$ respectively. A unit load at station 2 gives deflections at 1 and 2, i.e. b_{12} and b_{22} of $(1\times 2l)/K\times l$ and $\{(1\times 2l)/K\times 2l$ plus $(1\times l/K\times l)\}$, or $2l^2/K$ and $5l^2/K$ respectively.

Since the deflections are measured relative to station 0, the static equivalent of equation (6) in the present simple case is :

$$\left.\begin{aligned} y_1-y_0&=l^2/K(P_1+2P_2)\\ y_2-y_0&=l^2/K(2P_1+5P_2)\end{aligned}\right\} \quad . \ . \ . \quad (15)$$

In a steady harmonic vibration we can put $y_0=A_0\sin\omega t$, $y_1=A_1\sin\omega t$, $y_2=A_2\sin\omega t$, so that the inertia forces at full amplitude (replacing P_0, P_1, P_2) are respectively $m_0\omega^2A_0$, $m_1\omega^2A_1$ and $m_2\omega^2A_2$.

Substituting these values in (15) gives

$$\left.\begin{aligned} A_1-A_0&=\omega^2l^2/K(m_1A_1+2m_2A_2)\\ A_2-A_0&=\omega^2l^2/K(2m_1A_1+5m_2A_2)\end{aligned}\right\} \quad . \quad (16)$$

Since there is no resultant vertical force, we can use the condition

$$m_0A_0+m_1A_1+m_2A_2=0 \quad . \ . \ . \quad (17)$$

to eliminate A_0 from the L.H.S. of (16), and so give

$$\left.\begin{aligned} (1+m_1/m_0)A_1+(m_2/m_0)A_2&=\omega^2l^2/K(m_1A_1+2m_2A_2)\\ (m_1/m_0)A_1+(1+m_2/m_0)A_2&=\omega^2l^2/K(2m_1A_1+5m_2A_2)\end{aligned}\right\}$$
$$. \ . \ . \ . \ . \ . \quad (18)$$

or, since $m_0=m_1=m_2=m$ in the present example,

$$\left.\begin{aligned} 2A_1+A_2&=(m\omega^2l^2/K)(A_1+2A_2)\\ A_1+2A_2&=(m\omega^2l^2/K)(2A_1+5A_2)\end{aligned}\right\} \quad . \ . \quad (19)$$

In matrix notation

$$\begin{bmatrix}2&1\\1&2\end{bmatrix}\begin{bmatrix}A_1\\A_2\end{bmatrix}=\begin{bmatrix}1&2\\2&5\end{bmatrix}\begin{bmatrix}A_1\\A_2\end{bmatrix}\frac{ml^2\omega^2}{K} \quad . \quad (20)$$

and, as in (7) and (7*a*), we can invert the L.H.S. square matrix to give

$$\begin{bmatrix}A_1\\A_2\end{bmatrix}=\begin{bmatrix}2&1\\1&2\end{bmatrix}^{-1}\begin{bmatrix}1&2\\2&5\end{bmatrix}\begin{bmatrix}A_1\\A_2\end{bmatrix}\frac{ml^2\omega^2}{K}=$$
$$=\begin{bmatrix}2/3&-1/3\\-1/3&1/3\end{bmatrix}\begin{bmatrix}1&2\\2&5\end{bmatrix}\begin{bmatrix}A_1\\A_2\end{bmatrix}\frac{ml^2\omega^2}{K} \quad . \quad (21)$$

which, on carrying out the multiplication of the two matrices on the R.H.S. give

$$\left(\frac{3K}{ml^2}\right)\frac{1}{\omega^2}\begin{bmatrix}A_1\\A_2\end{bmatrix}=\begin{bmatrix}0&-1\\3&8\end{bmatrix}\begin{bmatrix}A_1\\A_2\end{bmatrix} \quad . \ . \quad (22)$$

The two equations represented by (22), i.e.

$$\left.\begin{aligned} (3K/ml^2\omega^2)A_1&=0A_1-A_2\\ (3K/ml^2\omega^2)A_2&=3A_1+8A_2\end{aligned}\right\} \quad . \ . \ . \quad (22a)$$

could have been derived at once from (19) in this simple case, but the process of inversion and multiplication as carried out by the machine saves an enormous amount of labour when there are thirty to fifty variables. This applies even more to the iteration process which is now performed on (22) to derive the two frequencies and modes corresponding to the equation of motion (22*a*).

A value of the quantity $(3K/ml^2\omega^2)$ is required (and hence of ω^2) and the corresponding ratio A_1/A_2 that will satisfy (22). As already described, arbitrary values of A_1 and A_2 are taken to start the iteration, say, $A_1=1$, $A_2=1$. Substituting these values in the R.H.S. of (22) we have, following the rule for pre-multiplication above explained,

$$\begin{bmatrix}0&-1\\3&8\end{bmatrix}\begin{bmatrix}1\\1\end{bmatrix}=\begin{bmatrix}-1\\11\end{bmatrix}=11\begin{bmatrix}-1/11\\1\end{bmatrix}.$$

Comparing this with the L.H.S. of (22) it is seen that $(3K/ml^2\omega^2)$, or λ^2 for conciseness, has to have the value 11 if A_2 is to repeat its unit value—this is the first approximation to λ^2. Repeating the process on the new column matrix gives

$$\begin{bmatrix}0&-1\\3&8\end{bmatrix}\begin{bmatrix}-1/11\\1\end{bmatrix}=\begin{bmatrix}-1\\85/11\end{bmatrix}=\frac{85}{11}\begin{bmatrix}-11/85\\1\end{bmatrix}=$$
$$=7\cdot727\begin{bmatrix}-0\cdot1176\\1\end{bmatrix}$$

showing that, with a value 85/11 for λ^2 the values $-1/11:1$ taken for the ratio $A:A_2$ results in a ratio $-11/85:1$—not very different. The next iteration gives

$$\begin{bmatrix}0&-1\\3&8\end{bmatrix}\begin{bmatrix}-0\cdot1176\\1\end{bmatrix}=\begin{bmatrix}-1\\7\cdot612\end{bmatrix}=7\cdot612\begin{bmatrix}-0\cdot1316\\1\end{bmatrix}$$

which, on being pre-multiplied once again by the square matrix, practically repeats itself,

$$\begin{bmatrix}0&-1\\3&8\end{bmatrix}\begin{bmatrix}-0\cdot1316\\1\end{bmatrix}=\begin{bmatrix}-1\\7\cdot615\end{bmatrix}=7\cdot615\begin{bmatrix}-0\cdot1315\\1\end{bmatrix}$$
$$. \ . \ . \ . \ . \quad (23)$$

Thus finally the highest value of λ^2 (i.e. $3K/ml^2\omega^2$) is 7·615, from which the fundamental frequency

$$\omega^2=3K/ml^2\div7\cdot615=0\cdot394K/ml^2 \quad . \ . \ . \quad (24)$$

The corresponding ratio $A_2/A_1=-7\cdot615:1$, from which it immediately follows from (17) that $A_0=-(A_1+A_2)=6\cdot615$ and therefore the complete mode is given by

$$A_0:A_1:A_2=6\cdot615:1:-7\cdot615 \quad . \ . \quad (25)$$

as shown in Fig. 4(*a*). The result, of course, agrees with the mode corresponding to the lower of the two frequencies obtained in the ordinary way from the quadratic in ω^2.

If in (20) we had inverted the R.H. instead of the L.H. matrix we should have been iterating for the highest value of ω^2 and not for $1/\omega^2$,

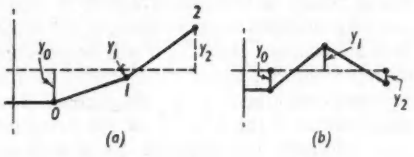

Fig. 4

and would then have derived the highest—and in this case the only remaining—frequency. However, the remaining frequency and mode will be derived as if it were the second of a large number, in order to illustrate the normal procedure. The second frequency therefore is obtained as the highest of those remaining after eliminating the fundamental.

Following the argument in the paragraph "Natural Modes and Frequencies" note that, since the forces m_0A_0, m_1A_1, m_2A_2 in any remaining mode A_0, A_1, A_2 do no work in operating over the displacements $A_0^{(1)}$, $A_1^{(1)}$, $A_2^{(1)}$ of the fundamental, we have the relation (since the m's happen to be equal)

$$A_0A_0^{(1)}+A_1A_1^{(1)}+A_2A_2^{(1)}=0$$

or, using (25),

$$6\cdot615A_0+A_1-7\cdot615A_2=0 \quad . \ . \quad (26)$$

But, as the resultant force must still vanish, (17) still holds, as that putting $A_0=-(A_1+A_2)$ in (26), we have

$$-5\cdot615A_1-14\cdot23A_2=0 \quad . \ . \ . \quad (27)$$

Thus here, by virtue of the second mode being the only remaining mode, the ratio $A_1:A_2$ is found at once as

$$A_2=-0\cdot394A$$

and, from (26) or (17), $A_0=-0\cdot605A_1$. Thus

$$A_0:A_1:A_2=-0\cdot605:1:0\cdot394 \quad . \ . \quad (28)$$

a mode shown in Fig. 4 (*b*).

The corresponding frequency in this case is at once obtained from either of equations (22*a*) as

$$\omega^2=7\cdot615K/ml^2 \quad . \ . \ . \quad (29)$$

The Antisymmetrical Case.—In the antisymmetrical case the governing condition is zero bending moment in the mid-section A^1A of Fig. 3 and not zero shear as in the symmetrical vibration. The mid-section is now free to rotate about its stationary centre O through any angle ϕ defined by

$$\phi=y_0/l_0 \quad . \ . \ . \ . \ . \quad (30)$$

thus producing additional deflections

$$y_0=\phi l_0,\ y_1=\phi l_1,\ y_2=\phi l_2 \quad . \ . \ . \quad (31)$$

Deformations of the beam are therefore to be measured relative to the straight line defined by the angle ϕ, so that the static equation (15) now becomes

$$\left.\begin{aligned} y_1-\phi l_1&=y_1-(l_1/l_0)y_0=l^2/K(P_1+2P_2)\\ y_2-\phi l_2&=y_2-(l_2/l_0)y_0=l^2/K(2P_1+5P_2)\end{aligned}\right\} \quad . \quad (32)$$

while the dynamic equation (16) becomes

$$\left.\begin{aligned} A_1-(l_1/l_0)A_0&=(\omega^2l^2/K)(m_1A_1+2m_2A_2)\\ A_2-(l_2/l_0)A_0&=(\omega^2l^2/K)(2m_1A_1+5m_2A_2)\end{aligned}\right\} \quad . \quad (33)$$

Instead of making the resultant vertical force zero, we now make the moment at the centre O zero by writing

$$(m_0A_0)l_0+(m_1A_1)l_1+(m_2A_2)l_2=0 \quad . \ . \quad (34)$$

and hence (with the m's being equal)

$$-A_0=+(l_1/l_0)A_1+(l_2/l_0)A_2 \quad . \ . \ . \quad (34a)$$

Substituting this in (33) after putting $l_1=3l_0$, $l_2=5l_0$, gives

$$\left.\begin{aligned} 10A_1+15A_2&=(m\omega^2l^2/K)(A_1+2A_2)\\ 15A_1+25A_2&=(m\omega^2l^2/K)(2A_1+5A_2)\end{aligned}\right\} \quad . \quad (35)$$

or, in matrix form—parallel to equation (20),

$$\begin{bmatrix}10&15\\15&25\end{bmatrix}\begin{bmatrix}A_1\\A_2\end{bmatrix}=\begin{bmatrix}1&2\\2&5\end{bmatrix}\begin{bmatrix}A_1\\A_2\end{bmatrix}\frac{ml^2\omega^2}{K} \quad . \quad (36)$$

which can now be iterated in exactly the same way as before.

It is important to note that, by making use of the symmetry of the beam, i.e. by fixing the central segment for the purpose of calculating the elastic coefficients, we have been able to split the problem of finding its four frequencies and modes into the two separate and simpler problems of finding, first, the two symmetrical, and, secondly, the two antisymmetrical, frequencies and modes. If any other segment of the beam had been fixed, there would, after later giving it linear and angular freedom, have been a fourth order instead of a second order matrix to iterate with, and therefore about six to eight times the computational labour.

It is also important to note that in the absence of symmetry, and so far as the amount of work is concerned, nothing is gained by fixing one segment (or one pair of stations) rather than another, since, with a total of n stations, we are always left with $(n-2)$ equations after allowing for linear and angular freedom of the fixed pair of stations (as compared with $(n/2-1)$ when symmetry exists. In practice, however, it is naturally better to choose for temporary fixation a part of the structure where the main masses are concentrated.

[This concluded the first part of the paper.]

Amalgamation of Generation Divisions

WE learn from the British Electricity Authority that it has been decided to amalgamate the North-Western and the Merseyside and North Wales Generation Divisions as an experiment to obtain experience in the working of a larger unit than the existing Divisions. The amalgamated Division will progressively be given increased responsibility for its operations in pursuance of the Authority's declared policy of decentralisation. The enlarged operating unit will be known as the "North-West, Merseyside and North Wales Division" and will be inaugurated on April 1, next. The Authority emphasises that the changes which must inevitably take place in effecting the amalgamation will be developed gradually and in such a way as to cause the minimum of hardship or disturbance to the employees concerned; the salaries and wages of employees will not be adversely affected. Mr. A. R. Cooper, controller of the North-Western Division, and Mr. P. Briggs, controller of the Merseyside and North Wales Division, have respectively been nominated divisional controller and deputy controller of the amalgamated Division.

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DEFENCE, 1954

A year ago, faced with the prospect of the continuation of the cold war, the Government felt obliged to impose a check on the rapidly rising rate of expenditure on rearmament and to spread the programme over a longer period, at the same time holding it to a lower peak. This policy is reaffirmed in the Statement on Defence, 1954, presented to Parliament last week. For the next few years our defence effort is to be maintained at the maximum which our economic capabilities permit. Estimated expenditure on defence for the current financial year was £1636¾ million and for 1954–55 it is proposed to spend £1640 million—an increase of £3,250,000 only. Included in these figures is U.S. aid, which amounts to £85,000,000 for the coming year. It would seem, therefore, that we must anticipate an annual expenditure of approximately this sum for a considerable time—a heavy burden on our economy, but there can be little doubt of the nation's willingness to accept it in the light of the abortive results of the Berlin Conference. The White Paper makes clear that there is to be a gradual change in the direction and balance of our defence effort. Greater emphasis is now to be placed on the Royal Air Force, for which a force of medium bombers is to be built up, as soon as possible, capable of using the atomic weapon to the fullest extent. Apart, however, from the platitude that a strong and efficient force of bombers is of the greatest importance to us, no urgent reason is given for this requirement. On the contrary, we are told that it is the ability of the highly organised and trained United States strategic air power to use the atomic bomb which remains the primary deterrent to a major war. Nor is the Government any more convincing in suggesting that, as the deterrent continues to grow, it should have an increasing effect on the cold war by making less likely such adventures as the Communist aggression in Korea. Would the United Nations approve—except as a retaliatory measure—the dropping of atomic bombs for mass destruction in the event of Persia, Afghanistan or some other small power becoming a pawn in the cold war?

In planning for the Army the Government is on firmer ground. A strategic reserve is to be built up at home, thus indicating the intention to return to our traditional policy of keeping available a small army for dispatch to areas where it will most hurt the enemy. How far it will be possible to implement this policy must depend on our overseas commitments and obligations. The maintenance of the strength of our Army on the Continent is stated to be a defence measure of the first importance, and it is thus difficult to see how the proposed reduction in the front-line formations can be carried out, unless the Government is reckoning on an early settlement with Egypt. A strategic reserve will, however, lose much of its value if the Royal Navy is not strong enough to convey it to where it is required—unless, in fact, the Navy has the number and types of ships required for offensive operations. The White Paper unfortunately does little more than emphasise the Navy's defensive function of safeguarding the sea communications, "which makes it unlikely that expenditure on the Royal Navy can be reduced much below its present level." A number of submarines are to be laid down—a wise decision in view of the age of our existing underwater fleet—but no new aircraft carriers or cruisers are to be ordered. It is fortunate, indeed, that the six carriers which have been building or under reconstruction since the war are nearing completion. For, at present, we have only five fast carriers and four of them, designed for piston engine aircraft, are no longer of much value except for anti-submarine operations. Nor is the cruiser position much better, five of our twenty-four cruisers having almost reached their age limit. On the other hand, a revolution, both in weapons and forms of propulsion, is now in progress and with all our other commitments the temptation to postpone the laying down of new large ships is understandable. Britain's defence programme forms part of a combined effort by the member nations of N.A.T.O., and, in view of the great strength of the United States Navy, N.A.T.O.'s urgent naval requirements are limited to the various types of craft needed to counter the modern fast submarine and new kinds of acoustic and other influence mines. In meeting these requirements this country has certainly done its full share. In addition to some seventy frigates—either new or converted from destroyers—no less than 150 coastal and inshore minesweepers are provided for under the present programme. The construction of these small ships has entailed a very considerable financial effort, a coastal minesweeper, a relatively slow vessel, costing about £450,000—£100,000 more than the price of a 36-knot destroyer leader of 1500 tons in 1937.

The White Paper adds that atomic weapons are now in production in this country and their delivery to the Forces has already begun. It is emphasised, however, in regard both to atomic weapons and guided missiles, that many are still in the development stage and it will be some years yet before we shall have enough to bring about any radical change in the pattern of our defence effort or to lessen the need for conventional forces. It is, in fact, the present strength of our Regular Forces which gives cause for anxiety. It is hoped by April, 1955, that the Regular Forces will have increased to 537,000 men—7000 more than in the current financial year—but there has recently been an appreciable decline in recruiting for all three Services. A still more serious problem is the continued loss of N.C.O.s and skilled tradesmen after their initial engagement—a problem which the Government seems to be making no effective efforts to solve. A section of the White Paper deals with Civil Defence, which is also stated to be short of manpower. Happily, during the past year there has been a marked improvement and there have been more recruits for the Civil Defence Corps than in any previous year.

TRAIN RESISTANCE AND TRAIN RUNNING

The measurement of train resistance is one of the most elusive studies undertaken by railway engineers. It is a natural corollary to the recording of locomotive performance, for without some knowledge of the magnitude of the train resistance it would not be possible to establish new train schedules by other than rule of thumb methods. The subject is of particular interest at the present time when much is being done to improve train services, and at the same time to secure more economical use of locomotives, rolling stock and fuel. Yet, although the resistance of a train on any one occasion is made up of a diversity of factors that make it almost impossible to lay down a formula by which the power needed to "time" a train may be computed, the problem of securing improved train running would be simple if there were none but engineering considerations to be taken into account. None the less a paper read before the Institution of Locomotive Engineers on Wednesday, February 10th, by Dr. H. I. Andrews renders good service to railway engineers and

operating men by providing a modern equivalent of the classic tests on train resistance carried out by Sir John Aspinall on the Lancashire and Yorkshire Railway in 1901. Whereas Sir John plotted his results as measured, and drew a fair mean curve through a swarm of points looking like a representation of the Milky Way, Dr. Andrews has attempted to separate the total resistance measured into components due, on the one hand, to the movement of the train in still air, and on the other to the effects of the natural wind. This follows up the work of F. C. Johansen some twenty years ago, who carried out a research with small scale models in a wind tunnel to determine the air resistance of various forms of passenger trains. Dr. Andrews has extended the previous experimental work by including measurements with a variety of goods vehicles.

In studying the paper, however, and considering the highly complex factors that affect the working of all classes of railway traffic to-day, one realises that the total train resistance made up variously of the running characteristics of the stock or the effects of the wind is very often not the dominant factor in governing the actual overall speed of express passenger and freight trains. The capacity of the locomotive may be determined with precision ; a good guess can be made at the value of the train resistance, but the resulting performance is all too frequently affected by signal delays. Some of these latter may be due to heavy occupation of the line, but in our experience far too high a proportion is due to the action of individual signalmen who carry out local movements with insufficient margin of time in front of through trains. The cost of such checks in coal alone must be considerable, but the resulting unpunctuality is to be deprecated from all angles, and not least for the demoralising effect upon engine crews. We do not believe that such operating blunders are the result of a " couldn't care less " attitude in signalboxes ; it is much more likely to be a lack of appreciation of the effects that may result. While so much is being done nowadays in the testing of locomotives, and in other ways to establish train schedules to suit economical working rates, it would seem that the campaign should be extended right into the main line signalboxes, with simple diagrams or small posters to show just how much coal is wasted when, for example, an express train is checked from 70 m.p.h. down to 20 m.p.h. The operating departments are, we know, taking a serious view of signal delays, and with certain trains of special importance all cases are the subject of reports to headquarters. But avoidance of delay altogether is worth a dozen inquests afterwards. There would be no point in spending a great deal of time and trouble in the improving of locomotive performance, or in conducting researches with a view to reducing the air resistance of coaching stock, if the higher speeds and the more economical use of fuel are to be nullified by unenlightened work by the signalmen along the line.

A few years ago one of the biggest obstacles toward the restoration of pre-war speeds of travel was the condition of the track. That obstacle now seems to be completely removed on most main lines, while from Dr. Andrews's paper it is most interesting and gratifying to see how much the resistance of coaching stock has been reduced in the past fifty years. While Aspinall's fair mean curve showed a resistance of 20 lb per ton at 65 m.p.h., with a scatter of ± 8 lb that could, we suppose, be attributed to adverse or favourable winds, Andrews gives an average value of 9·2 lb per ton for a train of eight coaches. This latter corresponds closely with the figure given in the recent Swindon test results with a " King " class engine. The additional figures quoted by Dr. Andrews, for various types of freight trains, will be studied with considerable interest, though an attempt to estimate with accuracy the resistance on any one occasion from a measurement of the strength and direction of the wind would almost certainly give misleading results, owing to the multitude of other factors involved. Engineers of the civil, mechanical and electrical departments have all made major contributions towards the improvement of train services. What now seems necessary, too, is an educational policy for the uniformed ranks of the operating staff. By such means a signalman might be caused to think twice before putting a yard pilot and half a dozen vans across the main line two minutes before a sharply timed express passenger train is due.

Obituary

WILLIAM LORIMER

We record with regret the death of Mr. William Lorimer, which occurred, after a brief illness, on February 18th, at 20, Mirrlees Drive, Glasgow. He was seventy-eight, and had spent the whole of his professional career with the North British Locomotive Company, Ltd.

Mr. Lorimer, who was the eldest son of the late Sir William Lorimer, was educated at the Albany Academy and at Glasgow University. At the age of twenty-two he joined his father, who was at that time a senior partner in the Glasgow locomotive building firm of Dübs and Co. This firm was founded in 1863, and forty years later was one of the companies which became part of the North British Locomotive Company, Ltd. Shortly after the formation of the North British Locomotive Company, Ltd., William Lorimer was appointed a managing director, and in 1935 he became chairman in succession to the late Sir Hugh Reid. He continued in that office until his retirement in 1946.

As managing director and as chairman, Mr. Lorimer carried a large share of responsibility for the affairs of the North British Locomotive Company, Ltd., particularly during the arduous years of two world wars. Despite the serious disability of blindness, which afflicted him twenty-eight years ago, Mr. Lorimer was able to retain a firm grasp of the many details and complexities concerned with a large business. In addition, he took an active interest in the affairs of the Locomotive Manufacturers' Association.

LOUIS V. DUNLOP

Many of the older members of the shipbuilding profession will have learned with regret of the death of Louis Vandalle Dunlop, in his seventy-sixth year, at Berkhamsted, Hertfordshire, on Tuesday of last week. Mr. Dunlop, who only retired in July of last year upon the completion of fifty-nine years in shipbuilding, was born in Greenock on March 7, 1878, and after completing his education at Greenock Academy in 1894 he entered the shipbuilding profession and served his apprenticeship in the drawing office of Caird and Co., Ltd. He subsequently rose to be chief draughtsman and head of the design department and was appointed yard manager in 1914. He continued to hold this post, after Harland and Wolff, Ltd., took over the shipyard of Caird and Co., Ltd., until 1928, when he became general manager of Harland and Wolff's yard at Govan. Some fifteen years later he was elected to the board of the company and continued as a director until 1953. For many years Mr. Dunlop was a member of the central board of the Shipbuilding Employers' Federation, of which he served a term as president ; he was also a past president of the Clyde Shipbuilders' Association. Louis Dunlop spent his life in shipbuilding and served on the council of the Institution of Engineers and Shipbuilders in Scotland ; he was also a member of the Institution of Naval Architects and a Liveryman of the Worshipful Company of Shipwrights.

JOHN ROGERS

We have learned with regret of the death of Mr. John Rogers, which occurred at Stafford, on February 15th. Mr. Rogers, who was sixty-one, had had a long association with The English Electric Company, Ltd., and recently relinquished the position of general manager of the company's works, on account of ill health.

John Rogers was born at Worle, Somerset, and was educated at the Merchant Venturers Technical College, Bristol, and at Bristol University, where he took a B.Sc. honours degree in engineering at the age of twenty. He served an apprenticeship with Willans and Robinson, Ltd., the predecessors of The English Electric Company, Ltd., at Rugby, and after its completion became personal assistant to the works manager. When The English Electric Company, Ltd., took up the development of the Fullagar oil engine, shortly after the first world war, Mr. Rogers was responsible for a great deal of the research work involved. He subsequently became assistant works superintendent at the Willans Works, Rugby, a position which he retained until 1927. In that year, Mr. Rogers left The English Electric Company, Ltd., to join Fiat British Auxiliaries, Ltd., Govan, as general manager. He returned to The English Electric Company, Ltd., in 1936 as general manager of the Stafford works, and two years later was appointed general manager of all the company's works.

Mr. Rogers was a member of the Institution of Engineers and Shipbuilders in Scotland and was a vice-president of the Stafford Works Engineering Association. He had also served on the Ministry of Supply industrial advisory council and on the general council of the Engineering and Allied Employers' National Federation.

BOOKS RECEIVED

Industrial Electronics. By R. Kretzmann. London : Clever Hume Press, Ltd., 31, Wrights Lane, W.8. Price 25s.

Microwave Spectroscopy. By M. W. P. Strandberg. London : Methuen and Co., Ltd., 36, Essex Street, W.C.2. Price 9s. 6d.

Dislocations in Crystals. By W. T. Read. London: McGraw-Hill Publishing Company, Ltd., 95, Farringdon Street, E.C.4. Price 36s.

Métrologie Appliquée. Second edition. By M. Denis-Papin and J. Vallot. Paris : Dunod, 92, Rue Bonaparte (VI). Price 480F.

Diesel Engines in Agriculture

(Contributed)

THE paper read by Messrs. L. Martland and R. M. Ogorkiewicz before the Diesel Engine Users Association on "Diesel Engines in Agriculture," comes at an opportune time and gives rise to much reflection. From the historical point of view a better title would have been "Oil Engines in Agriculture," since it is indeed a very long time since the petroleum engine was first used in the agricultural industry. We have only to think of such pioneers as Priestman, Capitaine and Akroyd Stuart to realise that the commercial history of the petroleum engine and its application in agricultural industry, goes back well into the nineteenth century. Even in the eighteenth century the mechanical engineer was busy with the mechanisation of agriculture. For example, in 1788 Andrew Meikle describes his threshing machine and remarks that it "is capable of being worked either by cattle, wind, water, or any other power." Thirty years later (1818) George Lenkensperger of Munich invented the pivoted stub axle with articulated control rod connecting the two axles. In 1825 Sir George Cayley devised a form of tracked vehicle, following this in 1837 with his hot air engine for the propulsion of road vehicles. By 1886 Priestman had arrived at a commercially successful petroleum engine. These few examples are sufficient to remind us that agricultural development owes an incalculable debt to the mechanical engineer. It is also true that the mechanical engineer has not lacked the encouragement of the enlightened agriculturist, an admirable instance being recorded by the late T. H. Barton, who prepared, for exhibition at the Royal Agricultural Society's Show held at Doncaster in 1891, the two Hornsby-Akroyd engines which were awarded the first prize for oil engines. It appears that one of these engines was purchased, at the show, by Squire Sitwell of Smalley Hall, Derbyshire, a pioneer in agricultural mechanisation. (See THE ENGINEER, August 23, 1946, page 170.)

In their paper Messrs. Martland and Ogorkiewicz deal for the most part with tractors and they show how great has been the development, during the last fifty years, of the internal combustion engined tractor. It is stated that as a result of the immense expansion in the use of tractors which has taken place since the 1939–1945 war, British agriculture has become the most highly mechanised in the world, there being more tractors per acre than in any other country, including the United States and New Zealand. We read that the petrol-engined tractor still predominates in the United States, where petrol is plentiful and relatively cheap. "The majority of other countries, dependent on imported fuels, have switched to the cheaper vaporising oil, and vaporising oil engines still hold pride of place in agriculture of most countries outside the North American continent." In Germany there was early concentration on the compression ignition engine, "so much so that now practically all of the 250,000 tractors in use in Germany are of the diesel or semi-diesel types." So far as Great Britain is concerned, the authors estimate that in 1953, "well over one-half of all new tractors supplied to the home market were diesel-powered." As for the particular type of engine used in British-built tractors "the air-cell and precombustion chamber systems have found no favour in tractor engines on account of their relatively high specific fuel consumption; this, in spite of having less sensitive fuel injection systems. There are, however, several engines with swirl type combustion chambers. The remainder use direct injection in open chambers, in line with the now fully established practice in the larger British road transport engines." The authors find that the most widely represented design "is the conventional four-stroke, multi-cylinder, in-line type, similar in many ways to road transport diesel engines." It could be added that this design applies not only to engines for tractors and road haulage vehicles but to engines for automobiles, as can be noted on any of the German highways. Four-cylinder engines are said to predominate and "water cooling is favoured by the great majority of makers and so, on the whole, are wet liners." Figures are given which show that in the case of British tractor engines, the power rating gives around 0·185 b.h.p. per cubic inch of engine swept volume while, based on rated maximum revolutions per minute, the mean piston speed is of the order of 1250ft per minute. These figures certainly reflect the submission of the authors that by reason of the higher average power loading factor in tractors and the more arduous conditions under which they work, agricultural engine rating is more conservative than in road transport engines; and so it is that at the present time tractor power units as a class "may truthfully be described as moderately rated medium speed engines."

In an analysis of the reasons which account for the higher cost of the diesel engine as compared with the spark ignition engine, the authors refer to the injection equipment as the main item, its cost representing "about one-fifth of the cost of the complete engine." It can hardly be doubted that just as the injection equipment is the very heart of the engine, so also must its preservation in pristine condition be a main objective in tractor engine maintenance. This is a subject upon which much light was shed by Dr. Hans Heinrich (of Robert Bosch G.m.b.H., Stuttgart) in his paper, "Filtering of Diesel Fuel," read before the Paris meeting in 1951 of the Congrès International Des Moteurs A Combustion Interne. Among other things, Dr. Heinrich pointed out that in petrol engines, all that had to be done was to keep down particle size below the size of the smallest carburetter hole. In the case of the direct-injection oil engine, however, where the clearance between the plungers and cylinders of the injection pumps is but a few thousands of a millimetre, the filtering of the fuel should be such as will "keep out particles of the order of 1/1000 of a millimetre." Dr. Heinrich went on to show how small impurities act entirely differently in diesel fuel and in petrol, the settling rate being—in both cases—proportional to the square of the radius of the particles, proportional to the difference in specific weights, and inversely proportional to the viscosity of the fuel. Particles of equal size sink in petrol twenty times as fast as in diesel fuel "and the settling rate of particles of admissible size is one million times as great in petrol as compared with diesel fuel." Consideration of these submissions may assist in explaining the persistence of petrol and vaporising oil engines in tractor service. They also lend force to the warning given by Messrs. Martland and Ogorkiewicz that "Too much emphasis cannot be placed on the need to observe cleanliness in the handling and storing of fuel as well as any parts of the fuel system."

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

SLIPPING OF LOCOMOTIVES

SIR,—I have noted in Mr. E. H. Livesay's article on "The Golden Arrow" (Victoria-Dover) that he says he would believe the "Britannia" class slips with a closed regulator if he saw a logical explanation of it.

On several occasions I have seen the Bulleid "Pacifics" commence slipping when starting a train after the regulator has been closed for as much as 30 seconds or more. To my mind, the explanation is forthcoming in the fact that, quoting the "Merchant Navy" class, the total volume of steam pipe plus two end steam chests is 2·6 cubic feet or 105 per cent of the cylinder volume at full cut-off of 70 per cent. This represents a very large reservoir of uncontrolled steam which can readily dissipate its energy in slipping.

Undoubtedly the "Britannia" class steam chest proportions are no less favourable than the "Merchant Navy" and, incidentally, this desirable feature was initiated in this country on the Great Western Railway during the early years of the present century by the late Mr. Churchward.

A. E. G. MASLIN

Swindon, Wilts,
February 19th.

Annual Report of the Chamber of Shipping

THIS week the Chamber of Shipping of the United Kingdom issued its annual report, 1953-54, in which attention is drawn to the problems to be solved by the shipping industry and comments made upon the main events of the year. With regard to the Suez Canal, the report emphasises that, apart from its value in wartime, it is essential to British economy that merchant ships should have undisputed free passage.

In round figures the report states that during 1953 world shipping increased by 2,750,000 gross tons, including 1,750,000 tons of oil tankers, and that the amount of tonnage withdrawn left the dry cargo fleets unchanged. The total of the United Kingdom fleet is stated to equal the 1951 figure, but foreign-going tramp tonnage increased, following two years of heavy disposals, as did tanker tonnage. It is stated in the report that new orders in 1953 totalled 520,000 tons gross and that to maintain the fleet orders for 700,000 tons per annum were required. This falling off in orders and the cancellations cannot be attributed to the shortage of steel, and the report insists that the real issue is the ability of the shipping industry to maintain its fleets and hence its share of world trade and its contribution to the country's economy.

The improved turn-round of shipping is attributed to the reduced volume of trade, and it is reiterated that ships spend too long in port, despite the improvement in port facilities. The report goes on to deprecate flag discrimination.

The report records intensification of German and Japanese competition and the rapid increase of the fleets of both countries and the progress in shipbuilding output. The financial position of Japanese shipowners is noted and it is stated that H.M. Government has been asked not to allow British shipping to be placed at a disadvantage due to Japanese shipping being Government subsidised. Comment is also made in the report upon the continued restrictions upon the sale of ships abroad and the stipulation that ships for scrap must be sold to the British Iron and Steel Corporation is adversely criticised. This condition of sale causes hardship to British owners, in that they are denied the benefit of higher prices from shipbreakers elsewhere; in effect the shipping industry is subsidising steel production and suffering a loss to its fleet replacement funds.

The report contains tables dealing with such items as world tonnage, United Kingdom tonnage, form of propulsion, construction returns, movement of shipping, Suez Canal traffic, freight index, trade totals, and bunkers and prices.

P. and O. Liner "Arcadia"

No. II—(*Continued from page 280, February 19th*)

The liner "Arcadia" has recently joined the fleet of the Peninsular and Oriental Steam Navigation Company and sailed on her maiden voyage in that company's service to Australia on February 22nd. A total of 679 first and 735 tourist-class passengers are carried and the ship, which has a length overall of 720ft and a gross tonnage of 29,734, is propelled at a service speed of 22·5 knots. Two sets of double reduction geared turbines develop a total propulsive power of 34,000 s.h.p. and take steam at 500 lb per square inch pressure and 800 deg. Fah.

First-Class Accommodation

ACCOMMODATION for the first-class passengers is provided in state rooms, having one, two or three berths, arranged on "A," "B," "C" decks, and also on "D" deck immediately forward of the dining saloon. Many cabins, mainly on "A" and "B" decks, have private bathrooms or showers attached and there are eight special cabins-de-luxe on "B" deck amidships which can be readily converted into sitting rooms by having an arrangement of stowing beds. The cabins are paired off in suites, two of them having verandahs, and, together with the inside cabins, are air conditioned.

The whole of the boat deck surrounding the casings is set out as a recreation space with deck tennis courts, quoit pitches and spaces marked out for the playing of a variety of games. Portable glazed folding screens are arranged between the lifeboat davit supports to give complete protection from the strong winds and to form a sun trap. Right forward on the same deck is a large observation lounge, immediately below the bridge, which has large windows fitted to port, starboard and forward and is equipped with portable armchairs fitted with foot-rests. In the centre of the space is a glass-covered table containing a chart showing the course of the ship and against the aft bulkhead is a bar flanked with figureheads of the sailing ship era. There are two "Warerite" wall panels, which have drawings incorporated into the plastic surface; one depicts the company's original ship, "William Fawcett," accompanied by a representation of the first "Arcadia," while the other shows the famous clipper ship, the "Cutty Sark," in company with a Chinese junk. The floor coverings include maps of the two hemispheres.

Forward of the foyer on the promenade deck and open to it is the library which we illustrate on page 322; it is furnished with settees, easy chairs, built-in divan seats and is panelled, together with the foyer, in honey-coloured sycamore and stripey elm with weathered bird's eye maple. To port and starboard are writing rooms which have concealed altar-pieces built in to the inboard walls and have all painted decorative schemes relieved by small framed paintings. Aft of the foyer two sets of double swing doors open on to the main public room, the lounge, illustrated on page 322, which has large windows and a central bay recess on each side and concealed fluorescent lighting. The ceiling is panelled and the floor covered with a fitted carpet while the furniture consists of an informal arrangement of settees, easy chairs, arm chairs and low tables. In addition to veneered panelling carried out in Canadian mottled maple contrasted with elm and honey sycamore and relieved by ice coral birch, there are two main decorations. One is at the forward end of the room and consists of an alcove, formed between the entrance doors, panelled in low relief in a number of small panels many of which carry an inlaid motif of a classical subject including the signs of the zodiac. At the opposite end is a wide, deep painted mural depicting an Arcadian scene.

Immediately aft of the lounge is the dancing space which extends the full width of the deckhouse and is enclosed by folding screens. There is a raised band platform, cane chairs and glass-topped tables and the space is also arranged for use as a cinema. Further aft, doors in Esavian screens give access to the verandah and pool cafes, and there is an island bar to serve both spaces. Facing the bar counter in the verandah cafe is a painted decorative panel representing an old style map of the world, while the decoration in the pool cafe consists of two murals displaying Venetian scenes incorporated in the surface of "Warerite" plastic panels. Both spaces are equipped with leather-covered hardwood furniture and plastic-topped tables while the panelling is carried out in quiet figured olive ash, light-coloured bird's eye maple and elm with teak trim. The swimming pool, which is adjacent to the pool cafe, is protected by folding screens and has dressing rooms to port and starboard and also a balcony.

In the vicinity of the main stairways on "A" deck there is a shopping centre and hairdressing saloons, while the bureau is located well aft on "B" deck. The main staircase, which is veneered in cream bird's eye maple and figured olive ash, rises from "D" deck to "A" deck, where it stops and is continued upwards to the boat deck at a point slightly further aft. Another staircase is situated aft and there are additional stairways abreast the boiler casings linking the cabins on "A," "B" and "C" decks with the public rooms. The children's nursery is in a separate house right forward on the promenade deck and deck space between the nursery and the main deckhouse is enclosed by portable barriers to form an open-air playground. From the foyer on "D" deck two four-leaf revolving doors give access to the spacious air-conditioned dining room which seats 366 passengers at tables for two, four, six and eight. The room which is illustrated on page 322, is about 100ft in length, extends for the full width of the ship and has a ceiling of acoustic material to reduce noise. In the decoration of the room veneers of English cherry, walnut and sycamore have been used and at the forward end of the room a cold buffet is arranged in a recess which carries a decorative glass panel representing Hermes arriving in Arcadia. At the opposite end of the saloon, which is broken up by panelled columns, is a sideboard surmounted by a mural, entitled "Arcadia," consisting of seven panels mainly concerned with representations of the labours of Hercules. Service to the dining saloon is through two three-leaf motor-operated revolving doors communicating directly with the galley, which is immediately aft.

Tourist Accommodation

More tourist than first-class passengers are carried on the ship and a total of 735 are accommodated in comfortable cabins, having two, four or six berths, situated on "D," "E" and "F" decks, while the public rooms and recreation spaces are found on the promenade, "A," "B," "C" and "D" decks. The swimming pool and dressing rooms and main recreation space are on the promenade deck, while on "A" deck there is a gallery furnished with a bar, to port, and a cinema room to starboard, both being fitted with hinge-up screens; also a shop and other amenities and promenade space. On the deck below is a dancing space fitted with hinged glazed screens and a verandah cafe illustrated on page 322; it is panelled in zebrano and ash veneers with leather-covered panels, and has central alcoves fitted with built-in divan seats. Immediately aft is a well equipped children's nursery, which is panelled as is the first-class nursery, with "Warerite" plastic sheets embodying suitable nursery scenes.

The entrance hall is on "C" deck and hinged doors open forward on to the lounge, which is decorated in French figured birch contrasted with elm and marquetry inlays symbolising music, painting and literature. Aft is the smoking room furnished with chairs upholstered in two tones of leather and this material is used for panels set into light-coloured paldao walls and mounted diamond-fashion with low relief carved panels. A tee stairway from the entrance hall leads down to a foyer on "D" deck, from which hinged doors open on to the dining saloon. This is arranged around a trunked cargo hatch and another staircase which links the public rooms on "C" deck and the dining room with the cabins on "E" and "F" decks. There are tables for four, six and eight and the saloon, which has accommodation for 376 people, is equipped with leather-covered birch arm-chairs and panelled in figured willow, elm and sycamore with walnut trim. The saloon is air conditioned and service from the galley,

Galley of Liner "Arcadia"

P. AND O. LINER "ARCADIA"

First-Class Library

Tourist-Class Verandah Cafe

First-Class Lounge, Looking Forward

First-Class Dining Saloon

which is forward, is through two three-leaf revolving doors.

Messrs. A. McInnes Gardner and Partners have been responsible for the designs of the decorations and furnishings and these have been carried out by Waring and Gillow, Ltd., in the public rooms, while the staircases have been the responsibility of Maples-Martyn organisation and W. Mason and Son, Ltd., were contractors for the shopping centres and hairdressing saloons.

Crew Accommodation

Immediately below the navigating bridge is the captain's house containing suites for the captain and staff captain and the chief officer's cabin, while the house below houses the remaining deck officers and includes a smoke room. The engineer officers have their cabins, including a suite for the chief engineer, about amidships and to starboard on "C" deck, while the medical staff are accommodated to port on the same deck in the vicinity of the hospital. Several members of the crew have single berth cabins forward on "B" deck, where there is also a recreation room, and both the European and Goanese stewards have their cabins forward on "C," "D" and "E" decks with their mess rooms on "C" deck amidships in the vicinity of the engine-room casing. The Asian firemen and seamen have their quarters aft on "E" deck and separate galleys and mess rooms aft on "C" deck.

Port Side of Laundry, Looking Aft

Hotel Services

The galley (illustrated on page 321) and associated service rooms are located on "D" deck between the first and tourist-class dining rooms. They are designed for economic working and fitted with a full range of equipment and several labour-saving devices. The main equipment has been the responsibility of Henry Wilson and Co., Ltd., and includes the electrically heated main range which has eighteen ovens and a total loading of 283·5kW. There are electrically heated hot presses, fish fryers and eight grills having a total loading of 112kW, and among the auxiliary fittings are a dough mixer, ice cream machines and a number of Hobart machines, including four dish-washing machines, each capable of cleaning 2700 pieces per hour.

The whole of the laundry requirements of the ship, passengers and crew can be dealt with by the laundry, which occupies a large compartment right aft on "D" deck, and our illustration shows the port side of the compartment looking aft. Isaac Braithwaite and Sons, Ltd., has supplied most of the equipment of washing machines, drying tumbler and ironing machines, while the large calender machine was manufactured by Manlove Alliot and Co., Ltd. On "C" deck, to port and slightly aft of 'midships there are three hospital wards (one of which is a maternity ward), an operating theatre, dispensary and consulting room. In addition, in a house right aft on "B" deck, is the isolation hospital and a general hospital for the tourist passengers and crew.

The mechanical ventilation system has been the responsibility of Thermotank, Ltd., and the company has also supplied the air conditioning plant.

J. and E. Hall, Ltd., has supplied the main refrigeration equipment which is arranged to form three distinct plants and the main forward group consists of four 140 h.p., 12in by 9in, twin-cylinder Freon compressors. Two of these are for cargo and provisions and two for air conditioning, but one of the latter is cross connected to the cargo and provision service to act as a standby. The machines have to serve the insulated cargo spaces, arranged for frozen and chill cargoes, chilled and quick frozen meat, the temperatures ranging from 33 deg. to minus 5 deg. Fah., while temperatures varying between 50 deg. and minus 5 deg. Fah. are maintained in the provision and bonded store rooms, which have a total capacity of approximately 34,000 cubic feet. The after group of machines consists of two 140 h.p. compressors for air-conditioning duty, while a 15 h.p. twin-cylinder Freon compressor is fitted to maintain a temperature of minus 5 deg. Fah. where required in the cargo and provision spaces. For serving the domestic refrigerating equipment two 27 h.p. twin-cylinder Freon compressors are fitted.

A total of twelve lifts of various categories have been supplied by J. and E. Hall, Ltd., including two lifts for the first-class passengers, each arranged to carry ten persons at 150ft per minute and serving six levels from "D" deck to the boat deck. There is also one ten-passenger lift, having a travel of 100ft per minute, for the tourist passengers serving eight levels from "G" deck to the promenade deck. The lift cars are constructed in wood veneered in ice-figured birch and the entrances are fitted with centre opening fire-resisting steel doors, while smooth acceleration, deceleration and accurate levelling are ensured by the Ward Leonard system consisting of a self-contained motor generator set operating traction drive motors. To port and starboard of the first-class entrances are baggage lifts, extending from the promenade deck down to "G" deck, each being constructed to carry a load of 1680 lb. There are also two stores lifts of similar capacity, one to port and one to starboard, which link the stores entrances at "D" deck with "G" deck and also a galley lift from "E" deck to "D" deck to lift 5 cwt. A lift to carry a load of 700 lb serves to link the linen store on "F" deck with the laundry on "D" deck and, for the convenience of the ship's engineers, there is a four-person lift which starts at "C" deck level and travels 33ft down to the engine-room. The service lifts have automatic push-button control and fire-resisting hinged shutter gates. For pantry service to the various decks there are two lifts, each of 224 lb capacity at 100ft per minute, extending from "D" deck to "A" deck and fitted with galvanised steel cars.

The lighting installation consists of tungsten lighting in conjunction with indirect cornice lighting for which both hot and cold cathode tubes have been used, and the equipment has been supplied by the General Electric Company, Ltd. This company has also provided the fire alarm systems, plural starters for the motors driving auxiliary machinery and the telephone system, which consists of automatic and manual units. There are four automatic units for staff intercommunication and the two-position manual board provides 500 extension lines for the passengers and six both-way shore lines.

(To be continued)

Centenary of a British Locomotive Works

This year marks the centenary of the steam locomotive designers and builders, Beyer Peacock and Co., Ltd., of Manchester. When the company was founded in 1854 by three principals—Charles Frederick Beyer, Richard Peacock and Henry Robertson—a works was opened on a 12 acre site at Gorton adjoining the line of the old Manchester, Sheffield and Lincolnshire Railway. The firm developed steadily in parallel with the growth of the railway systems of the world and as the demand for its locomotives increased the works were extended until they eventually covered an area of some 30 acres of the surrounding land.

Since 1932 the company has pursued a policy of expansion into other engineering fields and the group it now controls includes subsidiary firms manufacturing a wide range of mechanical and civil engineering products, refrigeration equipment, machine tools, agricultural and food machinery, and peat harvesting equipment. The main works is still primarily concerned with the design and construction of steam locomotives, but it is of interest to note that the associated company of Metropolitan-Vickers-Beyer, Peacock, Ltd., has a new factory near Stockton-on-Tees for the manufacture of electric, diesel-electric and gas-turbine-electric locomotives.

Although the company makes many other types of steam locomotive, mention of its name invariably brings to mind the "Beyer-Garratt" articulated locomotive, in the construction of which the firm has long specialised. This form of articulated locomotive was first conceived by the late Mr. H. W. Garratt, who in 1907 frequently visited the works as inspecting engineer for the New South Wales Government. The designs were developed in the drawing offices at Gorton for Mr. Garratt's first patent, and, although many and important developments based upon years of experience have been made, fundamentally the "Beyer-Garratt" locomotive of to-day adheres to the conception of 1907. The first locomotive to the new design was built in 1909, and it weighed only 33½ tons. Railways were at first slow to appreciate the advantages of this form of articulation for arduous duties, but with the experience gained and development in design the numbers in use steadily grew.

In connection with these articulated locomotives it is interesting to note that last year the company began delivering an order for fifty 4–8–4+4–8–4 "Beyer-Garratt" engines to the New South Wales Government Railways and one of them was described in detail in our issue of October 31, 1952. These locomotives, which each weigh some 255 tons and have a tractive effort of 59,560 lb, are stated to be the most powerful engines built in Europe. In order to provide a record of these interesting locomotives the firm has prepared a film entitled "Beyer-Garratt Locomotives on the New South Wales Government Railways," which describes graphically their manufacture and operation.

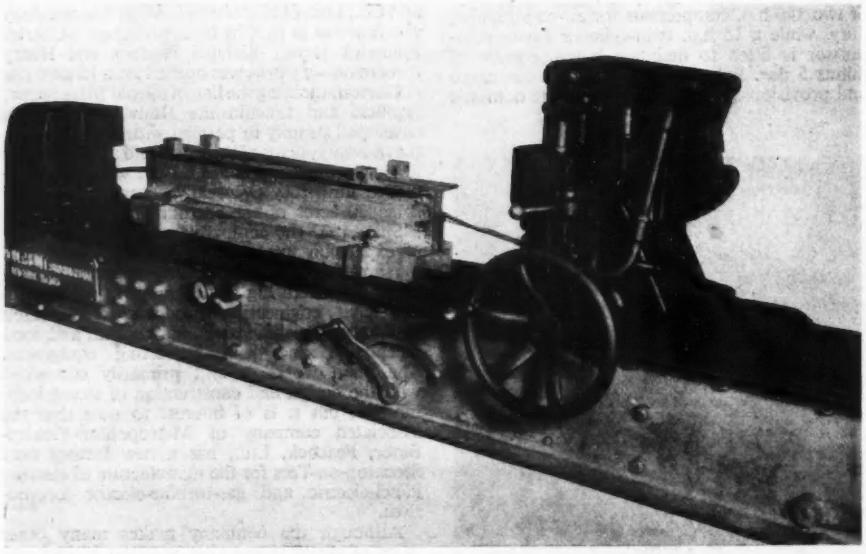
The Northern Models Exhibition.—The sixth models exhibition organised by the Northern Association of Model Engineers, is to be held in the Corn and Produce Exchange, Hanging Ditch, Manchester, from March 26th to March 28th next. The exhibits will include models of steam locomotives, boats, tools, aircraft, handicrafts, &c.

Universal Stretch-Forming Tool

The production of high-speed aircraft threatens to demand the use of more highly specialised machine tools, largely of American design, which are not only extremely costly, but tend to be inflexible even in their own special field. Several British aircraft firms are hoping to achieve a compromise by designing machine tools capable of satisfying though less automatically, the main requirement, but which are basically very much simpler, cheaper and more easily adaptable in the event of changes in design requirements. The machine described in this article is a good example of this policy and has been developed for stretch-forming operations at the works of Blackburn and General Aircraft Company, Ltd., Brough.

THE tools usually used for stretch forming are principally constructed of wood, as two complementary portions of a box shaped to receive a particular section and form it to a required curvature by forcing the portions together. The bent section is thereafter set by a stretching operation and such work is a familiar aspect of production, particularly in the aircraft industry. However, such tools are not only costly to construct both in material and labour, but also they are limited to bending a particular section to a particular contour.

The technique evolved by Blackburn and General Aircraft, Ltd.,* consists in the use of a novel, but simple and effective, tool capable of dealing with all varieties of sizes and shapes of section, which can be bent to any required contour. To this end these universal tools at Brough have been constructed from what might almost be classified as scrap, for the materials used are odd lengths of steel channel section and a few nuts and bolts. One of our illustrations shows the general configuration, and another shows some views and sections of the tool, explaining the adaptation of a simple tool to this process.



A Simple Application on the Stretcher Bed

Referring to *a*, *b* and *c*, which are the plan, side and end view of a typical tool, the essential parts are two channel section side members and a base plate, also of channel section. One side plate is made fast to the base, whilst the other is adjustably mounted so that it can be held parallel or at a slight inclination to the fixed side member. Inside each side member are rubbing plates 1, which can be compressed fibre or some such material attached to the metal to provide a sliding surface for the section being formed.

The side members are secured to the base plate by nuts and bolts, and for really heavy work there is provision for attachment at the top of the tool 2. For normal jobs, however, this has not been found to be necessary. In *a* there are two upper locations and three lower ones, but any number might meet the individual case, and *d* shows a tool with three upper bolts as well as six on the base.

The flexibility of the system applies both to overall length, as suggested in *e*, and overall height in *f*. The overall length is arranged to suit individual requirements; at Brough, for example, there are in use five universal tools, 7ft 6in, 6ft 6in, 5ft, 3ft 6in, and 2ft 6in, and it has been found that these multiples cover practically anything that is required. To cater for difference in height any number of channel sections can be bolted in whatever position they are required.

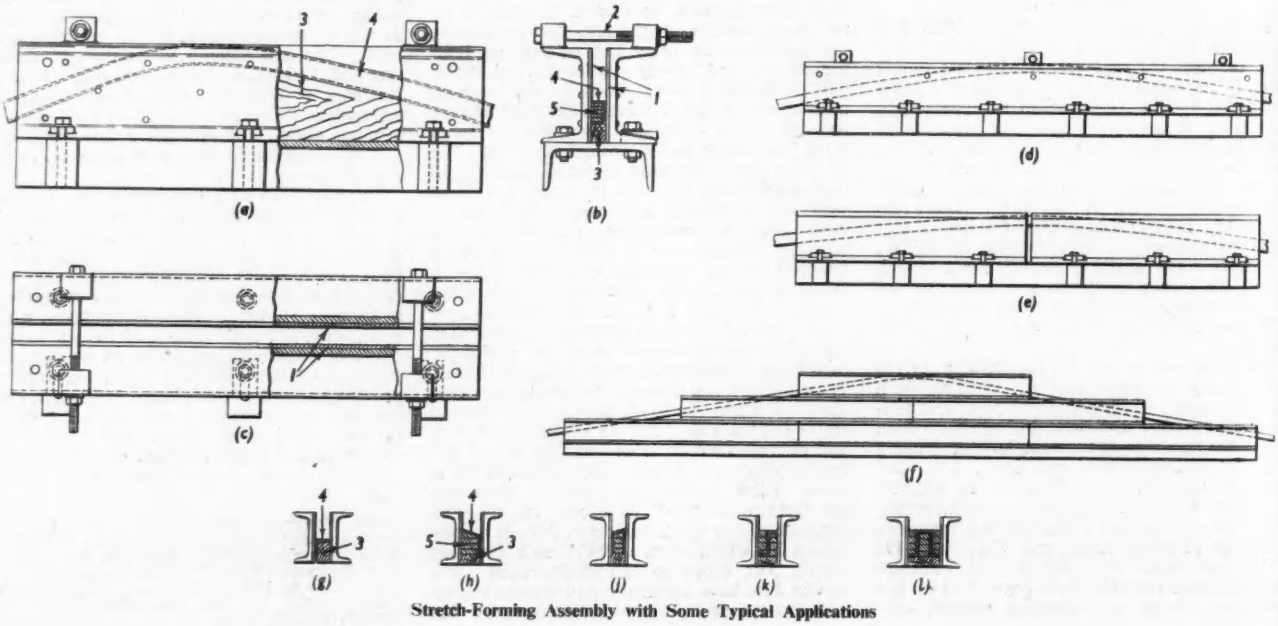
In practice a form block 3 to define the contour required is made of wood by simply sawing to the required shape; provided that it is carefully sawn this edge needs no further dressing. This form block may be made from practically any wood, commercial multi-ply being quite suitable. The form block need not be continuous, as the side members will give sufficient location and the form block will serve to locate the different lengths of universal tools if more than one is being used.

When sections are being formed in one plane only it is advantageous to have a form block made to the overall width of the section. The form block is placed on the base between the side members as shown in *a* and *b* and the side members set up to the form block and held in position by the bolts provided.

Thus the process involves placing the metal strip 4 together with, if necessary, the compressed fibre lathes between the side members; the ends are then forced down so that they can be inserted into the jaws of the stretching machine. This, on moving apart, stretches the section to conform to the contour of the form block and causes it to be set at that contour.

When the section to be formed is simple, such as an "L" shape at 90 deg., the section may be supported directly by the form block as shown in *g* and can be drawn down over the block by some hydraulic pull or other stretching medium. However, the majority of sections to be formed are more complex and must be supported by

* Patent applied for.



Stretch-Forming Assembly with Some Typical Applications

compressed fibre lathes 5, these being free to slide during bending, yet maintaining the metal strip to the required shape. This application is illustrated in *b*, *h*, *j*, *k*, and *l*. When heavy sections are being formed it is often necessary to fix the ends of the section into the stretching machinery and then the form block is forced against the metal strip by hydraulic jacks or other mechanical means.

Where the flange angle varies with length the variation of bevel can easily be made on the lathe when straight. In the case of the usual wooden boxes this work has to be incorporated on a curved surface involving much time and patience, so that small changes in bevel are often ignored due to this difficulty, this being to the detriment of the finished job.

The Blackburn method can be used to form sections of double curvature by forming a curve in one plane and then inserting a second contour block in the opposite plane. This is usually carried out as a second operation, depending upon the nature of the job. Also sections can be joggled under load by cutting the impression required either in the form block or fibre lathe, thus eliminating the usual troubles of the contour being distorted due to the joggle.

The five universal tools previously mentioned do the work, at Brough, of several hundred stretch-forming blocks hitherto employed, and thus effect an economy, for even the compressed fibre may be used over and over again or be re-cut for use with other sections. After the tools have been in use some little time these fibre lathes become standard equipment and only the basic form block is required with each different job. The tool is simple and easy to use, requires little storage room and the unrestricted access to the work through the open top of the tool greatly facilitates the manipulation of the metal section.

Developments and Experiments in the Mining Industry

In a paper presented to the Midland Branch of the National Association of Colliery Managers on February 23rd, Mr. E. H. Browne, the director-general of production of the National Coal Board, discussed and gave general particulars of some of the recent and novel current technical developments in the mining industry. We reproduce below some abstracts from Mr. Browne's paper.

IMPORTANT reserves of several coalfields extend under the sea. In Northumberland, Durham and East Scotland, very heavy expenditure on reconstruction and new sinkings is necessary to work the undersea coals. Inland, such capital investment would not normally be contemplated without the appropriate boring. Hitherto, the lack of adequate information has been accepted *faute de mieux*, since proving by forward drivages underground—the alternative to boring—is severely limited for practical reasons, apart from cost. But the absence of boreholes is a serious disadvantage, not so much because of any doubt as to the need for reconstruction or development to get the undersea coals, but because the general lines of the mining layout have at present often to be decided without the requisite information to ensure that they are rightly placed.

With this in mind, a firm of consulting engineers, responsible for erecting sea forts during the war, and a leading deep boring firm, were approached by the Board. As a result, it has been decided that, although the project must be regarded as speculative, a trial should be made with out-to-sea boring.

Boring will take place from a platform, similar to that used for the sea forts, which will be floated out and established for each borehole. When boring has been completed, the platform will be refloated and towed to other positions. The tower will be designed for any depth of water up to 20 fathoms, which is likely to be sufficient for boreholes up to a distance of 3½ miles from the shore off the north-east coast. The tower will be built of steel with a base of plate girder construction, carrying a steel plate deck 80ft square. It will stand about 170ft high from base girders to deck level and will weigh about 225 tons. A special drilling rig will be incorporated on the platform together with the necessary winch gear, living accommodation, diesel generators, cranes and other handling equipment, life rafts, &c. The drilling operation itself will not differ much from normal land boring, except, of course, that the distance from the platform to the sea bed will require a tube through which the drill rods will pass.

This is a very unusual enterprise, and it has required a certain amount of courage to decide to proceed with it, as the initial outlay for the tower and equipment is considerable. But the stakes are high. The insurance provided by successful boring against wrong or nugatory under-sea development would be of great value in relation to the enormous capital costs involved. The first experimental hole will go down off the coast of Fife, but the need for information off the north-east coast of England may well justify the transfer of the tower there after a relatively short time.

The possibilities of mechanical mucking for shaft sinking have been studied in the last few years, and in the knowledge that there were important developments in South Africa, an investigation was made early last year by Mr. F. Marsh and Mr. B. L. Metcalf. Amongst other interesting information the system adopted at Vlakfontein is given in their report.

The sinking platform comprises three stages or floors. From the top stage concrete from a Blaw Knox mixer is delivered into a chute and fed down to the middle deck and the periphery of the shaft in three tubes. The middle stage is used by men who place the concrete and lower the shuttering. The bottom stage carries the blasting, lighting, telephone and signalling cable drums, and suspended from a mono-rail beneath its deck is the apparatus for manipulating the cactus grab and the driver's cab.

The cactus grab itself is an important feature of the equipment. It is a modified form of that made by Priestmans, Ltd.; it is of 20 cubic feet capacity and it has eight jaws, operated by compressed air.

Experimental work is to be done with equipment on these lines at a new sinking in Lancashire and perhaps also in Scotland.

AUTOMATIC WINDING

During recent years several automatic winders have been built in this country, mainly for South Africa. Modern developments in both alternating current and Ward Leonard control incorporate a means of speed load compensation as well as marked improvements in the control of acceleration and electrical braking which should make it possible to enforce adherence to a prescribed speed cycle such as is needed for satisfactory automatic winding under all conditions. The Ward Leonard control has always been more precise than alternating current, but the effect of the new developments is to make the control of a.c. winders approximate more nearly to the Ward Leonard system and make it more adaptable to automatic control.

A 1225 h.p. automatic a.c. winder recently installed at Lynemouth Colliery in Northumberland can be controlled by the banksman from the surface landing place. Automatic winding promises to be a useful development. It should reduce the liability to accident through human error and should also increase winding capacity. The extension of lift practice to winders in Sweden, where there are many installations operated by push buttons, either in the cage or at landing places, has been closely studied.

LOCOMOTIVES

Over the last few years I have ventured, from time to time, to suggest that although diesel locomotives are at present predominant they are not necessarily to be regarded as the only or even the main answer in the long-term to our underground traction problem. It may well be that the lower maintenance cost of battery locomotives will prove to be a decisive factor. It is only fairly recently, however, that a 90 h.p. battery locomotive has been available. This is now in use and the results so far have been very satisfactory. The chief object of development in the case of battery locomotives is to obtain maximum battery capacity with the minimum size and weight.

The experimental trolley wire installation at Sandhole Colliery was put to work in July last year, since when it has carried the normal haulage load smoothly and satisfactorily. The tunnel in which it operates is about 1½ miles in length with an average gradient of approximately 1 in 100 in favour of the load and an output of 1200 tons to 1300 tons per shift. Four locomotives supplied by the Metropolitan-Vickers Electrical Company, Ltd., are employed, each 8 tons in weight and of 62 h.p. (one hour rated).

So far as novel developments are concerned, the "electrogyro" locomotive is the most interesting possibility in this field. The "electrogyro" method of energy storage for traction purposes was introduced by the Oerlikon Company of Switzerland. In essence, the equipment comprises a large storage flywheel which incorporates a change pole squirrel-cage motor and is brought up to speed by coupling to an electricity supply at conveniently located points. The gyro motor then acts as a generator, excited by an adjustable battery of condensers, and supplies power to the traction motors until lowering of the flywheel revolutions necessitates respeeding. The current produced by the gyro motor varies from 25–100 c/s and permits a wide range of speed control during the whole of the running period.

We decided in January, 1953, to try out a locomotive of this kind on the surface, for main line shunting work. (It seemed desirable to gain experience with this type of equipment on the surface before its introduction underground even for experiment.) The "electrogyro" unit is to be supplied by the Oerlikon Company, and the mechanical structure of the locomotive by Sentinel (Shrewsbury), Ltd. The locomotive will be fitted with two 5ft 3in diameter flywheels in cases containing a small quantity of hydrogen for cooling purposes, and each feeding a traction motor situated on the two axles. The time necessary to speed up to 3000 r.p.m. from zero will be approximately 20 minutes; from 1500 r.p.m. to 3000 r.p.m. takes only 3 minutes and so the common practice will be to keep the flywheel turning during standing periods by means of the application of a reduced voltage. Regenerative braking will be provided, but there will also be air braking activated by an electrically-driven compressor. The rates of acceleration and braking will compare favourably with those provided by normal traction equipment. Experience with this locomotive should enable us to assess the merits of this form of traction and should pave the way for underground use.

When transport is concentrated for efficiency—by installing either trunk conveying or a locomotive system—there are often new problems introduced in the handling of materials or small quantities of rock to and from the coal face or at repair points. To help to meet this difficulty in some cases, an attempt is being made to produce a vehicle with a self-contained source of power, which can be used without tracks and which will travel on fairly severe gradients. This proposed materials truck will have pneumatic tyres, and will be driven by a four cylinder, 30 h.p. diesel engine. A development contract for it has been placed with Coventry Climax, Ltd., and the prototype machine should be available within a few months.

COMMUNICATIONS

In the past, underground communications have not been given a great deal of attention, and consequently they have not kept pace with modern mining. Various present developments are aimed to remedy this.

There are several possible applications of radio equipment both on the surface and underground. V.h.f. radio telephones have been installed in some coalfields for communication between rescue stations and their vans, and other installations are being made.

Below ground normal radio communication appears to be impracticable, but wired radio communication is promising. Experiments have been carried out both below ground and in shafts in conjunction with two manufacturers. Two "Montavox" portable mine radio-telephone sets have been brought from Germany by one manufacturer and the other one has built his own prototype. The experiments have now reached a stage where further information needs to be obtained by large-scale trials, and equip-

ment should be available in certified prototype form this year.

In this paper it is appropriate to refer only to relatively new developments in power loading ; but I cannot help reflecting that whilst the development of new techniques and machinery ranks very high indeed in our priorities—since the diverse conditions of mining will call for many kinds of machines and methods—it is of equal and urgent importance to make more use of types of equipment now available.

There are three broad methods of mechanising the coal-getting and loading processes : (*i*) by cutting or slotting the coal. Most machines use some adaptation or combination of normal cutter chains, but disc and bar cutters fall into the same category ; (*ii*) by wedging or ploughing coal from the face. This category is dividing itself into fast moving—80ft per minute or so—machines which take a thin cut, and slow moving —10ft to 20ft per minute—machines taking a thicker cut ; and (*iii*) by rotary boring or similar processes.

(Mr. Browne then gave brief details of a number of different designs of coal cutters and ploughs being tried in British coal mines.)

A good deal has been published about augering in America, though it has not always been made clear that the amount of work done underground has been very limited, almost all production having been from opencast walls. But following an investigation made by an N.C.B. team sent out specially for the purpose, a number of machines have been imported and some interesting experimental work has been done. This work at the moment is largely held up pending the provision of means to ventilate the auger holes, an aspect of considerable importance from the safety side. British designs, more suitable to our conditions than the American equipment available, are being developed ; in particular the Board has a development contract with Robey and Co., Ltd.

There is one interesting development in conveying which I should like to mention. The Mining Engineering Company, Ltd., has produced an experimental " chain-belt " conveyor which has separate carrying and tension members. The tension member is a pair of steel cable link chains driven by sprockets. The belting—which is simply the carrying medium and is under practically no tension—lies deeply troughed on cranked axles having flanged wheels which run on rail tracks. The axles are connected to the driving chains, the connectors being in fact part of the axle. At the delivery end the top belt leaves the carriers at the driving gear and is supported to the remote drum by ordinary troughed idlers. At the return end the bottom belt leaves its carriers to go round a normal tension end and the chains pass round return wheels. The bottom belt is twisted at both the driving and return ends so that it is running with its dirty side uppermost. The manufacturers are most anxious to emphasise that this conveyor has yet to undergo trials under working conditions, and that some details in design in any case are being changed. The conveyor should therefore be regarded as still in the experimental stage. Nevertheless, it is an interesting possibility of which several important advantages will be evident.

Roadmaking

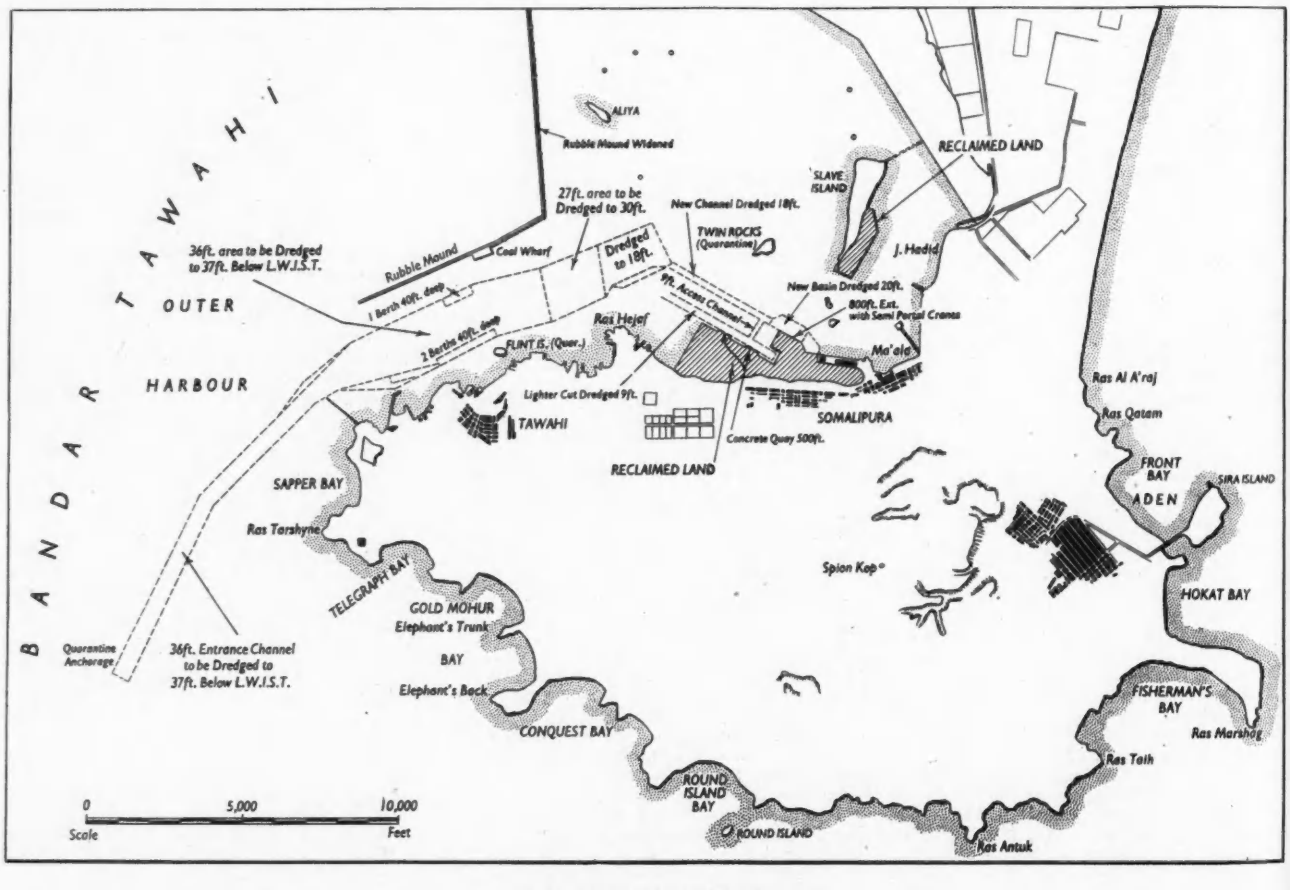
Over 600,000 manshifts are at present employed each year on the more important underground tunnels, and when some of the new horizon mines extend their opening out, tunnelling work will be on an increasing scale. The need for a road boring machine has long been felt and attempts have been made over a very long period to develop one.

At present work is being carried out on the American " Marietta Miner," which was designed for driving coal headings. For tunnelling work it will need substantial modification, and the two machines which we have brought over from the U.S.A. are to be regarded primarily as a basis for development. The first machine has been used experimentally in Scotland and has given important information. We now have a major redesigning task before us and there is a hard path to traverse before a tunnelling machine can be made available. But the necessity for it is very great and there is every justification for a concentration of effort on this project.

The Board is collaborating with the Ministry of Fuel and Power in an experimental 2000kW methane-fired, open-cycle gas-turbine installation at Stafford Colliery, where the Ministry is providing the turbine and the Board the installation, ancillary equipment, buildings, &c. Secondly, it is intended to operate this, or another similar, machine at Stafford on solid fuel plus methane. Thirdly, we have a project for an indirectly-heated open-cycle machine, the aim being to consume inferior fuel, including slurry.

Aden Port Development

The Trustees of the Port of Aden are to undertake a development scheme comprising extensive dredging and reclamation, together with the construction and equipment of medium draught and lighterage wharves for the coastal and entrepôt trades which, apart from bunkering, furnish the bulk of Aden's traffic. The extent of the new works is illustrated in the accompanying plan. A modern trading estate, with lighterage and road access, which will provide sites for packaging, processing and light industry, will be developed as part of the scheme. The consulting engineers for this work are Sir Bruce White, Wolfe Barry and Partners. Contracts amounting in all to about £2,000,000 for the first stage of the scheme are being entered into by the Trust with Pauling and Co., Ltd., for the construction work and with The Dredging and Construction Company, Ltd., and K. L. Kalis, Sons and Co., Ltd., for the dredging.



Development of the Port of Aden

Bokaro Thermal Power Station

(By Our Indian Correspondent)

The Bokaro power station, two 50MW units of which were brought into commission last February, is the first Damodar Valley project to be completed out of its seven schemes now under construction. The station, with an initial installed capacity of 150MW to be ultimately increased to 200MW, is the biggest single plant of its kind in India. It has so far cost about £9,000,000, of which just over two-thirds has been provided by the International Bank of Reconstruction and Development.

THE Bokaro power station has been conceived as an integral part of the multi-purpose Damodar Valley Project in Bihar. The inclusion of a thermal power station in what is predominantly a river valley scheme was necessitated by the fact that the firm hydro-power available from the system was only about 100MW for the first phase which had to be supplemented by firm power supply. The Damodar Valley Project envisages the construction of seven dams and a diversion weir on the River Damodar and its various tributaries, mainly for flood control and irrigation purposes but also for the generation of hydro-power and for navigation up the valley. Four main dams, Tilaiya, Konar, Maithon and Panchet Hill were taken up first and are in various stages of completion. Tilaiya, the smallest, is nearly complete (THE ENGINEER, March 20, 1953) and one of its 2000kW sets has already been commissioned. The Bokaro power station, on the banks of the Konar River, was also completed along with the Tilaiya power station and both were inaugurated by the Prime Minister last February. The station, with an initial capacity of 150MW to be ultimately increased to 200MW by a fourth 50MW set, will operate as a base-load station for about thirty-seven weeks in the year during the dry period, while the hydro stations are being utilised as peak stations; for the remaining fifteen weeks, covering the monsoon period, the station will function as a peak load station, the hydro stations acting as base load stations.

The power station is in Bihar, on the north bank of the Konar River, 3000ft below its confluence with the Bokaro River and about 12 miles below the site of the Konar dam. The main advantages of this site are its accessibility by rail and road, proximity to the collieries, facilities for cooling water supply from the Konar reservoir, good foundation conditions and ample space for the development of a small township. The general layout of the station and its ancillary works is given in Fig. 1.

Coal and Water Supply

The boilers are designed to use inferior coal (Table I) obtained by open-cut mining from the Bermo seam of the Kargali colliery, whose coal reserve is estimated at 50,000,000 tons against an anticipated annual requirement of 650,000 tons for a station of 150MW size. This is in accordance with the policy laid down by the Planning Commission, by which it is intended to reserve high-grade coal for metallurgical purposes.

Table I—*Fuel Characteristics of Bokaro Coal*

Moisture, Average	1 per cent
Maximum	10·00 per cent
Volatile matter	20·25 per cent
Fixed carbon	53·15 per cent
Ash, Average	26·60 per cent
Maximum	31·00 per cent
Calorific value (dry basis)	11,200 B.Th.U./lb
Fusion point of ash	2,282 deg. Fah.
Grindability	55 Hardgrove

The coal is carried by an aerial mono-cableway of capacity 200 tons per hour from the mines about 5½ miles from the site. There is also a railway for use in case of emergency. The loading station at the coalfields is a ground-level structure complete with a reinforced concrete loading bunker (capacity 1000 tons) from the chutes of which coal is loaded into the buckets. At the loading terminal near the power-house another reinforced concrete bunker receives the coal discharged from the ropeway buckets.

Each of the dual coal-handling systems at the power-house has a capacity of 250 short tons per hour of run-of-mine coal fed directly from the ropeway bunker or rail track hoppers to either of the duplicate conveyors. The duplex reciprocating feeders deliver the coal into the apron feeder which, in turn, discharges on to the inclined belt junction tower, whence it is carried either to the ground storage through the by-pass belt conveyor and dragline, or to the power-house belt conveyor through the coal crushers and magnetic separators. The coal from the ground storage, which holds a stock to last two and a half months, is reclaimed into the track hoppers by a dragline whenever required. This reclaimed coal is taken up the junction tower to be fed on to the power-house conveyor through the crusher and the separator as before. The run-of-mine coal crushed to ¾in size is conveyed into the boiler-house and tripped into the hoppers by means of an automatic tripper. The crushed coal from the hoppers is passed through weighing scales, feeders and bowl mills to the burners. The bowl mills are designed for a mill rating of 24,000 lb of coal per hour based on using coal with a maximum moisture of 10 per cent, a grindability index of 55 and pulverising to a fineness of 80 per cent through a 200 mesh screen. There is an electrical interlocking system for both raw and pulverised coal handling to prevent humping of coal at any point of fault in case of breakdown.

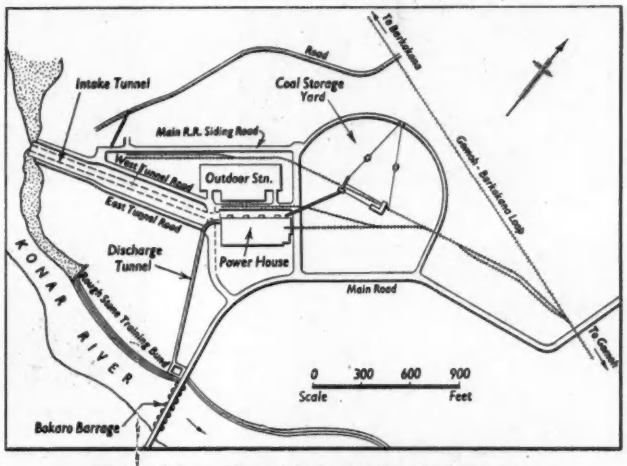


Fig. 1—Bokaro Thermal Power Station General Layout

A continuous supply of 400 cusecs of cooling water is required. For a good part of the year the Konar River remains practically dry and therefore a solid concrete " nappe " section barrage is constructed across the Konar River at the plant site, about 12 miles downstream of the Konar dam which, when completed, will control the storage at the barrage. The barrage (Fig. 6), with a storage capacity of 60 million cubic feet, is 884ft long with normal water level about 19ft above the river bed. Leading from the Konar River is a 1200ft long intake channel that serves as a settling basin for the station water requirements totalling 250,000 g.p.m. This design is necessary to overcome the extreme turbidity encountered during the monsoon season. The divided bar screen and stop gate structure is located at the south end of the building and feeds the intake channel. Each half of the intake channel feeds two screen pits, each of which serves one turbo-generator unit. Each screen pit is designed for two travelling water screens so arranged that, by means of shut-off gates, either half of the screen pit may be isolated and dewatered for repairs or cleaning of equipment or pit.

The discharge tunnel runs under the building for its full 450ft length, then turns and continues south-east to the discharge control structure 1200ft away. The structure is designed to discharge either above or below the barrage. The normal flow will be below; however, during the dry season when water is scarce, the discharge will be upstream of the barrage.

Steam Generating Units

The design is based on an initial installation of six boilers and an ultimate installation of eight. Two units are used for supplying steam to each 50MW turbo-generator set. The boilers are each designed for continuous operation with an output of 300,000 lb of steam per hour at 895 lb per square inch and 910 deg. Fah. The boiler is a double-drum radiant unit having a continuous tube, pendant, two-stage superheater with a centre gas by-pass and automatic and remote damper position selectors for steam temperature control. The high pressure and temperature are being attempted for the first time in India and Asia. Each steam generator is equipped with four burners. Two pulverisers are provided per boiler; one feeds the two lower burners and the other the two upper ones (Fig. 5). Each pulveriser is sized to carry 80 per cent of the full load. The station has been designed for pulverised coal fuel, but heavy-duty lighting-up equipment has been supplied to act as pilot torches in case of coal shortage. Each steam generator soot blower system consists of six manually operated wall-blowers, twelve manually operated straight-line blowers and two remote electrically operated retractable blowers.

An automatic air-operated combustion control system is provided. Coal firing is controlled in parallel with air supply, the induced draught being readjusted in accordance with steam flow/air flow relationship. The pulveriser feeder and mill exhauster inlet ratio controllers function in accordance with limiting relays to cut down the supply of fuel in proportion to the supply of air available. The automatic combustion control system operates to maintain the steam pressure changes within ±2 per cent and furnace excess air within ±0·05in of water, provided the rate of change of load on the boiler is within 20 per cent of its capacity in any one minute.

Table II—*Predicted Performance of Steam Generating Units*

Evaporation, pounds per hour	300,000
Temperature at superheater outlet, deg. Fah.	910
Pressure at superheater outlet, pounds per square inch gauge	895
Superheater pressure drop, pounds per square inch	33
Feed water temperature, deg. Fah.	415
Fuel firing rate, pounds per hour	32,800
Combustion rate, B.Th.U. per hour per cubic foot	17,000
CO_2 leaving boiler, per cent	15
Gas leaving boiler, pounds per hour	360,000
Air leaving air heater, pounds per hour	268,000
Gas temperature leaving boiler, deg. Fah.	720
Gas temperature leaving air heater, deg. Fah.	325
Air temperature entering air heater, deg. Fah.	80
Air temperature leaving air heater, deg. Fah.	636
Draught losses :	
Furnace, inch of water	0·15
Superheater and boiler, inches of water	3·40
Air heater, inches of water	2·95
Ducts, inch of water	0·60
Performance :	
Heat rate, B.Th.U. per kilowatt	9,500
Water rate, pounds per kilowatt	7·68
Overall thermal efficiency, per cent	36·00

The combustion control is also capable of manual operation.

Each steam generator is served by an f.d. fan driven by a constant speed motor. Volume regulation is obtained by inlet vanes operated by air-actuated controls. Each f.d. fan (on the fan floor 70ft above the operating floor) takes suction from the room, forces the air through a

BOKARO THERMAL POWER STATION, BIHAR, INDIA

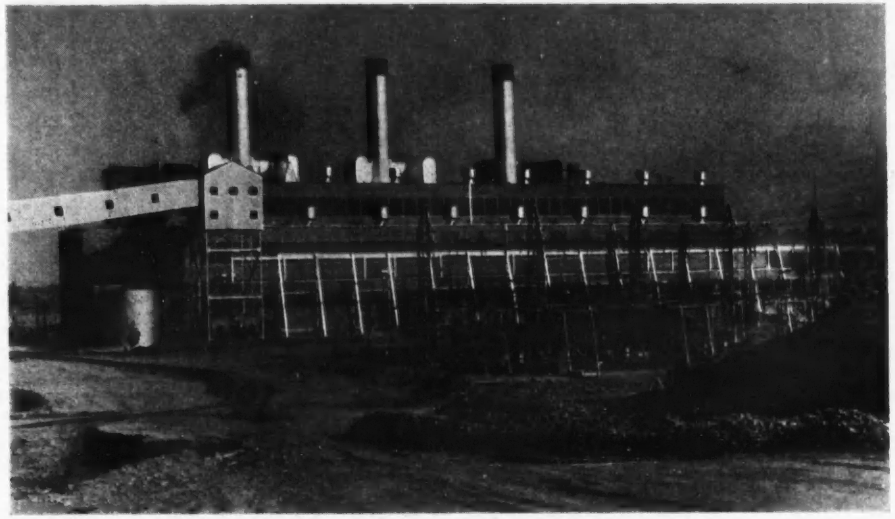


Fig. 2—Bokaro Power Station and Outdoor Substation

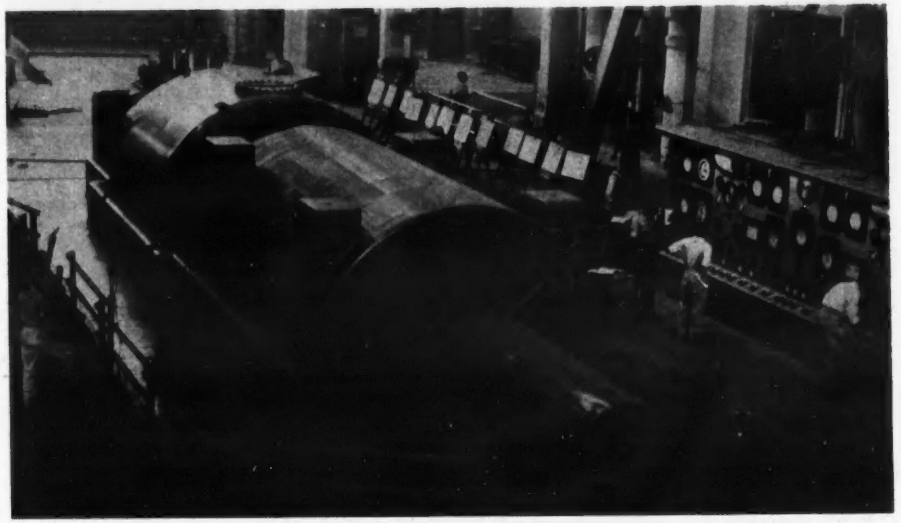


Fig. 3—57MW Hydrogen-Cooled Turbo-Generator

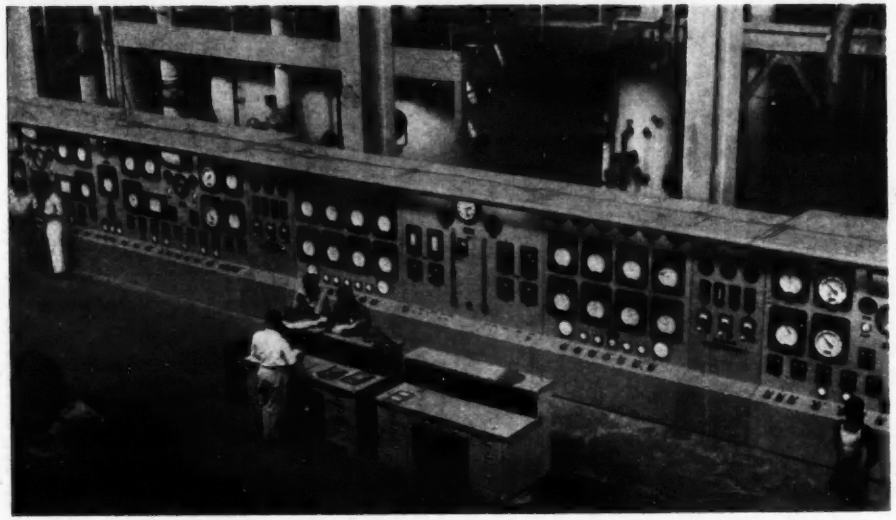


Fig. 4—Boiler and Turbine Control Panels for Nos. 1 and 2 Generating Sets

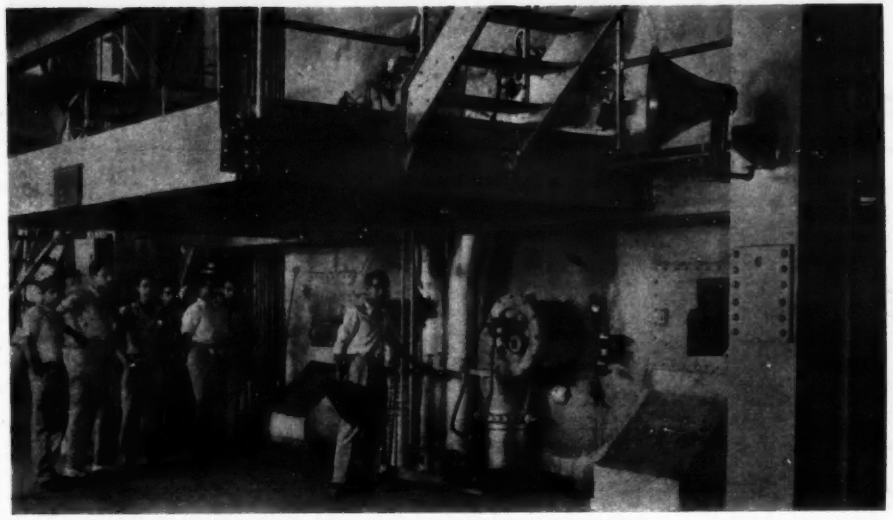


Fig. 5—Front of No. 1 Boiler

regenerative air preheater, and then through the duct work to the windbox and burners. Tempering air ducts with automatically-controlled dampers are provided between the windbox and each of the pulverisers to ensure the proper temperature in the mills. Each i.d. fan, driven by a constant speed motor, draws the gas from the steam generator, through the air preheater, mechanical dust collector and ductwork to the fan, and discharges the gas through the uptake and breeching into a self-supporting steel stack 14ft in diameter at the top and 85ft high.

Ash Handling System

The ash-handling system is designed to handle bottom ash at the rate of 240 tons per hour or fly ash at the rate of 60 tons per hour per unit. These capacities are based on the use of coal having maximum ash content of 31 per cent and ash-removal once in eight hours. Although only six boilers are now being installed, the design of the ash removal equipment permits future total of eight boilers.

The bottom ash or ash accumulated in the furnace hopper of each steam generating unit is removed by a hydraulic system consisting of oscillating feed nozzles to move the ash from each hopper to the sluiceway, along which the ash is conveyed by transport nozzles to the clinker grinders mounted next to the ash pit. To ensure a minimum water pressure of 125 lb per square inch at the oscillating and transporting nozzles, three vertical, 1800 g.p.m., 150 lb per square inch ash water pumps are provided, one of which will act as a spare. Two 4000 g.p.m. ash pumps are provided, either of which is capable of handling the combined ash and ash removal water from the system. These pumps will transfer the ash and water from the ashpit through especially hardened cast iron pipe to the fill area east of the power-house.

To accommodate the continuous cooling water flow from the furnace hopper deflectors and other miscellaneous plant drains, a concrete bilge sump and two vertical bilge pumps of 900 g.p.m. capacity are provided. The fly ash accumulated in the boiler pass, air heater duct, collector and stack hoppers is removed by a vacuum system. The system contains a hydraulic ejector for each set of two steam generators. The ejector produces a vacuum causing the fly ash to be moved through a pipe system from each hopper to the ejector when the individual hopper dust valves are opened consecutively. The dust is then mixed with the water stream and discharged to the sluiceway.

Turbo-Generators

Steam is supplied from two boilers to a 50MW, 0·85 p.f., 3000 r.p.m. turbo-generator (Fig. 3). Each tandem compound double-flow turbine drives a 13·8kV hydrogen-cooled (0·5 lb per square inch) generator, having direct-connected, geared, main and pilot exciters arranged lengthwise along the turbine hall. The condensing turbine has twenty-one stages and is designed for 850 lb per square inch, 900 deg. Fah. steam at the throttle, and is provided with five extraction openings. Cooling water for the hydrogen coolers and turbine oil coolers is supplied from the station service system. Gland sealing water and water for bearing packing is supplied from an overhead condensate head tank. Each turbine exhausts to a 50,000 square foot single pass, cross-flow condenser equipped with divided water boxes and a built-in cross-over valve so that one-half the condenser may be cleaned while the other half is in service. Each condenser is designed to condense 327,880 lb of steam per hour when supplied with 50,000 g.p.m. of circulating water at a temperature of 76 deg. Fah.

Feed Water Cycle

River water from the discharge tunnel is pumped to the water treatment building at the south-east corner of the plant proper by either of the two 300 g.p.m. vertical raw water pumps. The water treatment coagulation and precipitation plant has a 300 g.p.m. flow rate, at a surface rate not exceeding 1 g.p.m. per square foot and a retention time of not less than ninety minutes. Clarified water is uniformly decanted from multiple troughs and is collected in a concrete clear well adjacent to the rectangular precipitator basin. Three 300 g.p.m. pumps are provided to pass the clear well water through the pressure filters and carbonaceous Zeolite softeners to the concrete treated water storage tank. One pump operates continuously, the second starts up automatically when the header pressure drops and the third is used as a spare. Two 180 g.p.m. treated water pumps supply the demands of the make-up deaerators and evaporator descaling systems. This water is also used for an emergency supply to the turbine packing head tanks.

A 17,000 gallon condensate supply tank is connected with the inlet to each unit deaerating heater. A low water level in the deaerating heater will cause the line control valve to open, thereby operating a pressure switch which energises either of the motor-driven condensate transfer pumps, allowing condensate to be pumped from the condensate supply tank to the deaerating heater. The pump is de-energised automatically when the deaerator level and line pressure is re-established. In addition, one 150,000 gallon, 30ft diameter outside storage tank is provided as an emergency source of condensate for the unit condensate supply tanks. The condensate level in the supply tank is maintained to allow space to store feed water drained from any two boilers during an emergency shut-down. A condensate storage transfer pump is provided to transfer the condensate from the common header and interconnecting piping to the outside storage tank.

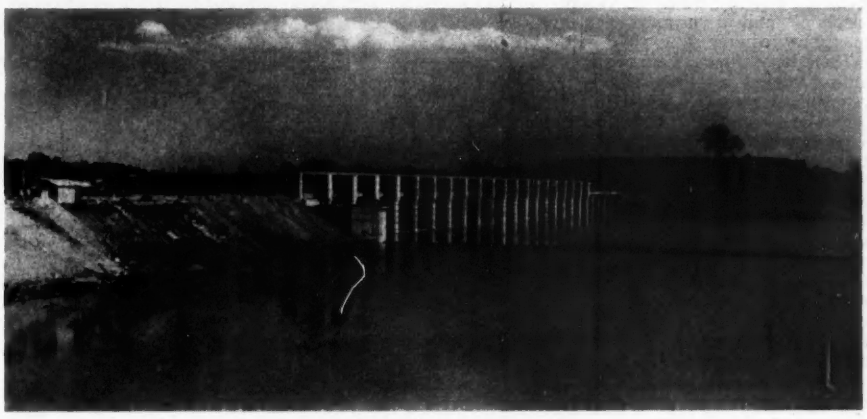


Fig. 6—Upstream View of the Bokaro Barrage

Electrical Plant

Each generator and its associated equipment constitutes an independent unit and is connected directly to the primary of a 65MVA, three phase, 13·2/138kV forced oil, water-cooled outdoor transformer. At the end of this bus run potheads are provided and cables are run underground in fibre-duct to the step-up transformers housed in the outdoor substation. This cable run consists of four paper-insulated, lead-covered cables per phase. Each cable has a neoprene jacket over the lead for protection against electrolysis.

From each generator a cable connection is carried from the 5000/6250kVA, 13,200/3150V station service transformer located outside the west building wall to supply the unit auxiliaries.

Each generator neutral lead is provided with one bushing current transformer for differential relaying. The leads are "bussed" together and earthed through a 50kVA, 13,200/220V distribution transformer. The secondary of this transformer is connected to a 0·63 ohm resistor. A voltage relay is connected across the resistor and sounds an alarm on the duplex switchboard if a ground fault occurs. Since the high earth impedance limits the earth fault current to a very low value, the generator is not taken off the line automatically if an earth fault occurs. The delay gives the operator time to shift the load to another machine or station.

Each generator is direct-coupled to a 220kW, 250V exciter, which in turn is excited by a 4·4kW 250V direct-coupled pilot exciter. The generator voltage is controlled by an indirect-acting voltage regulator which operates the motor-driven exciter field-rheostat.

Station Auxiliaries

Each generating unit is provided with a 3150V and a 400V station auxiliary busbar. The 3150V busbar derives its power directly from the generator through the 5000/6250kVA, 13,200/3150V transformer. The 400V busbar in turn derives its power from the 3150V busbar through the 1250kVA, 3000/400V transformer. These two unit busbars serve all the auxiliaries for their respective generator units.

In addition to the normal auxiliary supply there is a 5000/6250kVA, 138,000/3150V reserve transformer which is connected directly to a breaker on the 138kV busbar. This transformer is connected to the reserve 3150V busbar. This reserve busbar supplies power to the station essential auxiliaries such as coal handling, ash handling, fire pumps, &c. In addition, this busbar provides standby and starting-up power to each 3150V unit auxiliary busbar and serves the 1250kVA, 3000/400V reserve transformer. This reserve transformer, in turn, supplies 400V power to the station essential auxiliaries and standby power for each 400V unit busbar. If loss of voltage occurs on any one of the unit 3150V busbars, the load is automatically transferred to the reserve busbar.

All the auxiliaries of this plant are electrical. The larger essential motors, 200 h.p. and above, are 3000V and each is connected to an individual electrically operated air circuit breaker on the 3150V busbar. All other motors, ½ h.p. to 200 h.p., are 380V. The larger of these 380V motors are connected to individual, electrically operated air circuit breakers on the 400V busbar. The smaller, 380V, motors are served from the 400V busbar in groups, each group making up a motor control centre.

Outdoor Substation

Each 65,000kVA generator transformer is provided with two 2½ per cent rated kilovolt-ampere taps above and below normal high voltage with a manual no-load tap changer. These transformers are in the outdoor substation. The three unit 3150V station service transformers are outside the west building wall.

The 138kV outdoor substation is on the west side of the power-house and is remotely controlled from the duplex switchboard. A main and transfer busbar arrangement is provided. The main busbar is sectionalised through motor-operated disconnecting switches so that one section of the busbar can be removed from service for maintenance and repair. A busbar tie-breaker is provided. Any line breaker may be taken out of service for routine maintenance or repair and replaced by this busbar tie-breaker.

Each breaker is provided with motor-operated isolating disconnect switches. Each line breaker is also provided with a motor-operated breaker by-pass disconnect switch which connects the line to the transfer busbar. Each generator breaker and the reserve transformer breaker

are also provided with a motor-operated disconnect switch which connects the breaker to the transfer busbar. The motor-operated disconnect switches are interlocked with their respective breakers to ensure proper operation.

All the 138kV breakers are oil insulated and have pneumatically operated mechanisms. Each breaker is equipped with six standard bushing current transformers for relaying. In addition, each feeder has two bushing current transformers for metering and one bushing potential device for synchronising. The operation of this outdoor station is controlled from the duplex switchboard in the electrical control room.

Control Centres

There are two steam generator and turbine control centres arranged on the operating floor in the turbine bay (Fig. 4). The first control centre includes panels for steam generators Nos. 1, 2, 3 and 4, and turbine generators 1 and 2. The second control centre for the present includes only panels for steam generators 5 and 6, and turbine generator No. 3. The panels are complete with all normal instrumentation and controls, including internally illuminated instruments and remote flame indicators. One fifty-four-point annunciator desk is provided opposite each turbo-generator panel and includes a unit intercommunication speaker telephone and a private telephone to meet emergency requirements.

There are three steam generator auxiliary control centres on the operating floor in the steam generator bay. They include instrumentation and controls for superheater control, soot blower control and boiler operator instruments and telephones.

The electrical control of the station is centred on a duplex switchboard in the electrical control room overlooking the turbine room. This board contains the controls for the generators, exciters, generator transformers, station service transformers and the outdoor substation. A mimic busbar showing all main connections is provided on the front of the switchboard. The coal-handling and ash-handling systems are also controlled from central panels in the crusher house and the basement respectively. Electrical interlocking ensures proper sequence of operation of the equipment.

The generating sets are designed to operate normally on automatic control under constant as well as varying load conditions. The turbine governing system is actuated hydraulically by oil pressure generated by a centrifugal pump on the turbine shaft. In general, other mechanical control systems are operated by compressed air. The combustion control system automatically distributes the effect of fluctuating requirements of steam by the turbine alternator on the two boilers equally; controls the fuel feed of each boiler to maintain the desired steam pressure at any load; controls the furnace draught maintaining a negative pressure under normal operating conditions; controls the forced draught to maintain the fuel/air ratio, and controls the pulveriser mill temperature so as to avoid fire hazards or inefficient grinding due to wet coal. Other controls provide for control of steam leaving the superheater, feed water, water levels in feed water heater and hot wells.

Relay Protection

A separate differential protective scheme is used for the generator, main step-up transformers and the 3150V station service transformers and high-speed tripping and selectivity are ensured. The generator is protected by high-speed "product-restraint" differential relays. For back-up protection voltage-restraint over-current relays, which trip only on a high current and low voltage, are used. The main step-up transformer banks and the 3150V station service transformers are protected by harmonic-current-restraint percentage differential relays. The two kinds of restraint present in these relays prevent tripping on magnetising inrush current and heavy through currents. For back-up protection of the transformers, inverse time induction over-current relays are provided. The 138kV outdoor substation is protected by high-speed differential relays which operate in two to three cycles. Each 138kV feeder is protected against phase-to-phase and three-phase faults by directional distance impedance relays, and against phase-to-earth faults by directional ground relays.

The 3000V motors are provided with thermal relays for indicating an overload on an annunciator and with short circuit protective relays for tripping the breaker on the occurrence of a fault. In addition, each 3150V busbar has inverse time induction over-current relays for back-up protection.

The control voltage for this station is 250V d.c. A 120-cell lead acid storage battery having an eight hour discharge rate of 80A is installed in a battery-room on the electrical gallery. Two 10kW motor generator charging sets are provided: one floats across the battery and the other is used as a standby.

Main Building

The main building (Fig. 2) is 170ft by 450ft. The turbo-generator bay, 46ft wide, has a 125-ton overhead crane; the heater bay has a 25-ton overhead crane. The electrical bay is 24ft wide. The main roof of the building is 118ft above the basement floor and the four steel stacks, 85ft high, are supported on main roof steel girders. The entire structure is of structural steel imported from the United States and consisting of heavy section rolled joists up to 3in web thickness.

The main operating floor of the turbines and boilers is at ground level and is reinforced concrete slab; the upper floors and platforms of metal gratings are removable as required. The four turbine generator foundations are of reinforced concrete, entirely independent of the main structure, which has been designed to withstand moderate earthquake shocks. The length of the building and the temperature differential of 85 deg. Fah. necessitated a continuous expansion joint midway through the building.

Cost

The Kuljean Corporation of Philadelphia, U.S.A., was responsible for the design and supervision of the station and the International General Electric Company of New York was the main contractor. The contract was placed on February 13, 1949, ground broken at site on December 29, 1949, and the station opened by the Prime Minister on February 21, 1953. Costs have been going up steadily since the original budget and it is expected that the final figure will be nearer Rs.13·5 crores or approximately £10,000,000. This figure includes the civil engineering work for the fourth unit but excludes the cost of plant and equipment for the unit. Roughly, therefore, on the basis of this estimated cost, the capital cost per installed kilowatt works out at Rs.800, or £60.

Automatic Welding Blowpipe.—With the conventional blowpipe the correct flame—neutral, oxidising or carbonising—is obtained by the operator setting the recommended pressure readings on the outlet gauges of both oxygen and acetylene regulators and then manipulating the blowpipe valves. During welding it is frequently necessary to withdraw the blowpipe flame for short periods, during which time valuable gases are burned to waste or alternatively the gases are shut off and time is lost in flame readjustment. To avoid this waste the "Automatic" welding blowpipe has been developed by British Industrial Gases, Ltd., 32, Victoria Street, London, S.W.1. This blowpipe is operated in the usual way, once the original flame adjustment has been made, but thereafter the operator controls his supply of oxygen and acetylene simply by moving a thumb control backwards and forwards. The forward movement brings the full welding flame on while the backward movement shuts it off, leaving only a pilot light. The blowpipe is available in two sizes for welding up to ¼in mild steel plate and for heavier sections.

American Engineering News

(By Our American Correspondent)

Testing of the Arroyo Seco Prestressed Concrete Bridge

As the result of a joint programme of tests conducted by the California State Division of Highways and the Institute of Transportation and Traffic Engineering at the University of California, interesting data have now become available relating to the structural behaviour of a prestressed concrete bridge over the Arroyo Seco channel in Los Angeles. The Arroyo Seco bridge is a pedestrian crossing with a single span of 110ft. A half-elevation of the bridge is shown in Fig. 1, while a half-section at midspan and also one at quarter-span are shown in Fig. 2. The bridge was designed for a total live load of 22 tons, uniformly distributed. The construction and testing of the bridge proceeded in the following manner. In the first instance, the two girders of the bridge were precast near the bridge site. About a week after the casting of each girder, alternate layers of wires (thirty wires in the upper cable and thirty-five wires in the lower cable) were elongated 1in in order to take up shrinkage and to prevent cracks. The final prestressing, which required the elongation of all wires by about 6in each, was done after both girders were more than twenty-eight days old. Then the cable enclosures were pressure grouted. Concrete was placed on the ends of the girders to embed the anchorage fixtures. Finally, the girders were hoisted on to the abutments, deck moulds were constructed on the girders, deck steel bars were erected, and the deck concrete was placed. The prestressing was performed by the Prestressed Concrete Corporation of Kansas City, Missouri, using a method patented by that firm. In the first instance, the wires were cut to equal length, and for each wire a button head anchorage was cold formed at each end by a heading machine. Then the wires were inserted in the metal sheaths, and were stressed one layer at a time, with five wires to the layer.

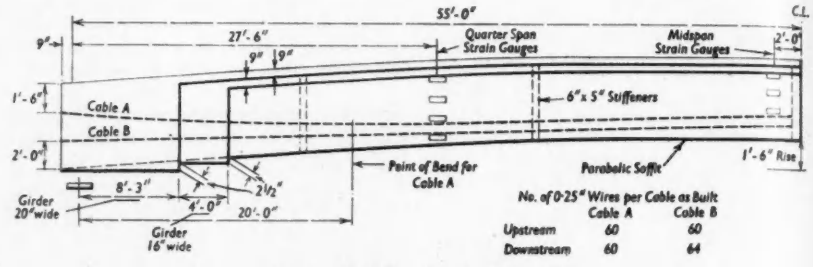


Fig. 1—Half Elevation of Bridge Girder

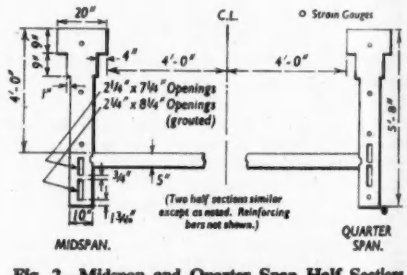


Fig. 2—Midspan and Quarter Span Half Sections of Bridge

For the purpose of testing, the completed bridge was loaded with 530 sacks weighing 94·5 lb per sack, or a total of 50,000 lb, to represent the design load. The next day, this load was doubled by adding another 530 sacks. After all the test load was taken off, a "Gunite" finish coat was applied to the bridge, the weight of the coat being estimated to be about 66 lb per linear foot of bridge. Seven Carlson strain gauges were installed in each girder, three near mid-span and four at quarter-span. Strain and deflection readings were taken both during and after prestressing and also at different stages of the testing pro-

cedure. It is planned that the strain gauge readings will be continued as long as it is feasible, in order to yield some data concerning the long-term behaviour of such girders.

The prestressing wire was ¼in in diameter and was ordered to have the chemical composition: Carbon, 0·60 to 0·85 per cent; manganese, 0·70 to 1·00 per cent; phosphorus, 0·050 per cent maximum, and sulphur, 0·550 per cent maximum. Furthermore, the following treatment was specified by the prestressing contractor:—"The cold-drawn prestressing wire shall be heat-treated after the final drawing in order to remove plasticity and increase the elasticity of the steel. Thereafter, the wire shall not be redrawn or cold worked in any manner to remove the elasticity developed by the heat-treatment."

Concrete for the girders was specified to possess a minimum ultimate compressive strength of 5000 lb per square inch, as determined by 6in by 12in test cylinders at twenty-eight days. The maximum allowable compressive stress in design was 1700 lb per square inch. The concrete mix contained seven sacks of cement per cubic yard, with 62 per cent of coarse aggregate and 38 per cent of sand. The maximum size of aggregate was 1in. Eight cubic yards of this mix with a water-cement ratio of 0·60 were first placed in the upstream girder. Test cylinders from these 8 cubic yards produced a strength of 6250 lb per square inch at twenty-eight days. This mixture, possessing a 1¾in slump, proved too stiff for good workmanship among the heavy reinforcing bars in the ends of the girder. A water-cement ratio of 0·65 was, therefore, adopted for the remainder of the upstream girder, and placing proceeded without further excessive difficulty. This latter mix produced a strength of 5500 lb per square inch at twenty-one days. For the downstream girder, concrete of 4in slump was used and the strength obtained averaged 5000 lb per square inch at twenty-one days. It may be noted here that the lower strength of the downstream girder might have been partly responsible for the higher strains and deflections subsequently found in that girder.

The total initial working prestressing force was to be 715,000 lb per girder, to be furnished by a sufficient number of wires at a working unit stress not higher than 60 per cent of the average ultimate tensile strength of the wires. The wires were to be stressed to 110 per cent of the working stress, held for two minutes in order to minimise creep, then lowered to 106 per cent and anchored—the additional 6 per cent being intended to counteract losses due to the elastic deformation of the concrete and the "take-up" in the fixing devices resulting from the prestressing operation. This procedure was thus designed to give the required initial working prestressing force of 715,000 lb at the time the prestressing operation was completed. For purposes of design it was assumed that the eventual losses due to creep and shrinkage of concrete and creep of steel would reduce the final working prestressing force to 85 per cent of the initial value of 715,000 lb. Since the wires furnished were of 0·05 square inch cross-sectional area and could safely carry a working stress of 120,000 lb per square inch, a total number of 119 wires was required. For additional safety, it was decided to use 125 wires per girder, arranged with five wires to a layer. The amount of prestress in each girder was primarily measured by a calibrated pressure gauge attached to the hydraulic jack as it was successively applied to each layer of wires, the same pressure being maintained for all layers irrespective of their sequence in stretching. However, the concrete girder shortened gradually as more wires were tensioned. This gradual shortening of the girder produced a successive loss of prestress in the wires, especially in those which were tensioned first.

Among the more important results of the tests obtained to date are the following:—(1) The measured elastic deflections and length changes of the girders agreed quite closely with those computed by the usual elastic theory. However, an apparent sluggishness of the girder deflections in responding to the test load has not been satisfactorily explained. (2) Since the concrete deck was poured after most of the shrinkage and creep in the girders had taken place and also since the deck is situated below the centroidal axis of the girders and is, therefore, subject to tensile strain from the girders, free shrinkage of the deck was prevented and transverse cracks were observed in the deck at about 5ft intervals. (3) The initial prestress computed by means of the jack pressure gauge was about 6 per cent higher than that computed by the elastic lengthening of wires, after correcting for various initial losses in both cases. It is felt that this difference of 6 per cent would be less if possible frictional loss along the length of wires were also considered. (4) The initial loss of prestress due to the prestressing process and the elastic shortening of the concrete was about 8 per cent, which was 2 per cent higher than that assumed in the design. After the initial loss had taken place, further loss of prestress due to the creep of steel and the shrinkage and creep of concrete was about 12 per cent in eight months, which was 3 per cent smaller than that assumed in the design. (5) As a result of the rainy season, which lasted while the girders were ten to twelve months old, a recovery of about 3 per cent of prestress in the girders occurred so that at the end of that season the prestress was about 89 per cent of the initial working value. (6) After prestressing, and while the girders still rested on the ground, the stress distribution was rather uncertain, since the condition of end support furnished by the ground was variable and not definitely known.

15,000-Ton Hydraulic Forging Press

Operation of a 15,000-Ton Hydraulic Forging Press

A 15,000-ton hydraulic forging press has now been in operation at the Cleveland works of the Aluminum Company of America for over a year and has already processed some 5,000,000 lb of light alloys. The press, which is shown together with its mechanical manipulator in the accompanying illustration, was built early in the last war by the Schloemann Company, of Düsseldorf, Germany, and was transferred to Cleveland, Ohio, after the war under an arrangement with the U.S. Air Force. The machine has a length of 22ft, a width of 18ft and extends 18ft below and 36ft above floor level. The components of the unit weigh a total of 1500 tons.

Due to the experience which has now been gained in the use of such a large press, the techniques for forging large light alloy components have progressed from an experimental to a production stage at the Cleveland works. Until recently most of the company's experience in the production of light alloy airframe forgings had been on hammers, ranging from very small units of 2000 lb or 3000 lb up to hammers of 35,000 lb and 40,000 lb capacity. In addition, many small and medium-sized forgings have been produced on mechanical forging presses of up to 2500 tons capacity, and on hydraulic presses of 1500 to 3000 tons. All the design proportions and related engineering standards recommended to customers in the past had been established primarily on the basis of hammer fabrication. Since March, 1952, when the 15,000-ton hydraulic press went into production, some thirty or forty sets of new press dies have been constructed and quite a number of large hammer dies have been adapted for press production. Whilst the company does not feel able at this time to present design factors and standards which can be applied generally to press forging practice, there are certain clear indications which have been established and which should be of assistance to those responsible for the engineering design of large light alloy press forgings. In general, the results obtained have been quite encouraging from the standpoints of surface quality, dimensional uniformity, reduction of required draught angles, ability to produce thinner webs and ribs, and increased die life. According to the firm no improvement over hammer forgings has been noted in mechanical properties or metallurgical quality and none was expected.

Surface quality has been improved greatly, as may be noticed by greater smoothness and freedom from laps, folds, and other dfeects which have to be chipped out between hammer operations or ground out and polished upon final inspection. This improvement is believed due to the forging being blocked or finished in a single stroke of the press, so that the small abrasions and slivers, developed as a result of repeated hammer blows, are avoided. The dimensional uniformity from forging to forging has been better than expected. The forging dies are designed so that they come together and, although they sometimes do not do so in hydraulic press operations, a high degree of uniformity in total pressure and unit pressure does exist from forging to forging. Consequently, if temperatures, dwell, and lubrication are controlled accurately, the resultant dimensional uniformity is generally good. The problem of controlling all of these factors, however, was not always easy and requires constant effort and refinement. The draught angles, which are standard at 7 deg. and are rarely less than 5 deg. in hammer forging practice, can be reduced easily to 5 deg. to 3 deg. in press forging. The most important reason for this is the ability to incorporate "knockouts" in the dies, which is not practical in hammer dies. It has been found possible to use thinner webs and ribs for forgings

manufactured on presses, the reduced draught angles being partially responsible for this improvement. Superior lubrication, higher die temperatures and the possibility of a "dwell" under pressure are other important factors contributing to this result. With regard to die life, the company considers its experience as satisfactory. There have been no major die failures, although a large hard plate holder was broken as a result of an operating error. Since few components had been produced in any substantial volume, the die mortality record cannot be taken as an index of future experience.

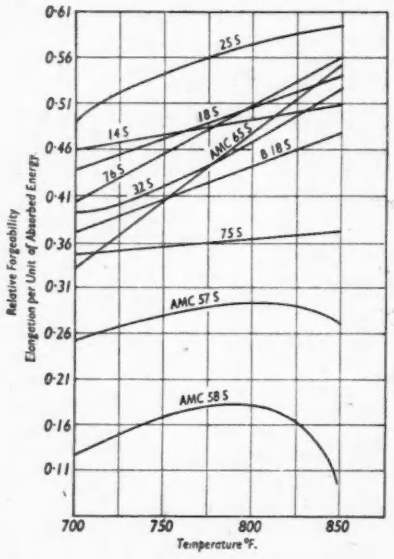
To-day, aircraft designers are anxious to obtain from the manufacturers forgings of thin web sections with thin ribs. The conditions which must be achieved to produce such forgings of relatively large area to fairly precise dimensions may be summed up as "reduction and control of required unit forging pressures." In the opinion of the company, far too much emphasis frequently has been placed upon press "size" or "capacity" in the belief that extremely high pressures will produce a complex forging in any size. If a press has a capacity of 50,000 tons and a forging requires a pressure of 40 tons per square inch to "flow," the machine can produce a piece only about 35in square. However, if by skilful design and fabricating practices this required pressure can be reduced to 15 tons per square inch, the press can fabricate a panel about 30in by 100in. Thus, a 50,000-ton press becomes equivalent to approximately 150,000 tons; or, conversely, it may be reduced in effectiveness to approximately 15,000 tons.

In the actual production phase of the press forging process the objective has been the promoting of a smooth flow of metal and the holding of unit pressure requirements to a minimum. It has been found that the hotter the dies the lower will be the flow resistance. However, the hotter the dies the greater is the problem of die lubrication and also the problem of maintaining certain dimensional tolerances, so that, altogether, it is necessary to obtain a proper balance of many factors which can be determined only by trial and error. At present it is considered impractical to press forge very thin sections, such as those contemplated for integrally stiffened wing panels. Such sections, ranging from 0·060in to 0·120in, can be obtained only by subsequent machining. So far, the company has succeeded in forging some webs of 0·180in thickness in rather heavily restricted sections, up to about 100 square inches in area, the total area of the forging being about 300 to 450 square inches.

Forgings having thin webs and thin ribs, together with small draught angles, have presented definite problems in straightening. In producing such parts warping is apt to occur during the forging operation and during heat-treating. Relying upon die or hand straightening, or a combination of both, it has been found difficult to hold such forgings to a very close straightness tolerance. The ejection from the dies of thin-web forgings with small draught angles has occasionally resulted in distortion or even piercing of forgings. Forgings having very small draught angles present a problem of removal from the straightening die which may lead to the use of mechanical ejectors. Such ejection may cause a bow and may require hand straightening after die straightening.

The stock which is now being employed for large hydraulic press forgings comes to the press from a number of other hot-working operations. It includes rolled bars and shapes, rolled plate, extruded bars and shapes, and bars forged from ingots. The working of ingots by forging, employing a variety of working cycles, appears to be a desirable method of producing stock for large press forgings. Sufficient working, together with the desired grain orientation, can be accomplished by utilising such preformed or preforged shapes. The forging stock is produced under closely controlled conditions, including ultrasonic inspection. An intermediate or "in-process" inspection of forgings occurs between successive forging operations. Through these methods of control it is believed that any discontinuities associated with ingot unsoundness have been largely eliminated. The relative forgeability of aluminium alloys also affects the problems of production, and the accompanying graph shows the relative forgeability of several commonly used American forging alloys. The curves were obtained through a measurement of the deformation of specimens with known energy absorption or through testing tensile-impact specimens at modified elevated temperatures. It will be noted that the relative forgeability improves considerably with an increase in temperature. The normal forging temperature for most alloys is about 800 deg. Fah., cracking or rupturing occurring if the forging operation is performed at substantially higher or lower temperatures. The forgeability of an alloy determines to a large degree the number of "blocking" operations required in order to attain a shape suitable for forging to size in a finishing die. Thus, the more difficult an alloy is to forge, the greater are the number of operations required to deform the forging stock sequentially to its desired shape. An alloy that is relatively easy to forge, such as "25S" alloy, should require fewer operations and fewer dies than the same part forged in "75S" alloy. In general, it has been established that the higher-strength forging alloys have poorer forgeability than the lower-strength alloys.

At present the Aluminum Company of America is having difficulty in obtaining sufficient die sinking sources for its die requirements



Relative Forgeability of American Aluminium Alloy

on the 15,000-ton hydraulic press. It is frequently not realised that some forging designs could be of such a nature that six months would be required for the construction of a set of finishing dies only, assuming that a die sinking machine is utilised eight hours a day for six days a week. With all of the American aircraft companies going to larger and closer tolerance forgings, it is apparent that a sufficient number of large machines will have to be constructed so that the necessary die sinking capacity will be available.

Unexpected changes in dimensions have sometimes been encountered during the machining of aluminium alloy forgings. These changes are commonly referred to as distortion and they may cause airframe manufacturers trouble during extensive machining operations of large die forgings. Such dimensional changes are believed due to localised overheating during machining, redistribution or relief of residual stresses imposed during heat-treatment, and exceeding the yield strength of the part by improper chucking or machining fixtures, or by excessive loading of the part at the tool tip due to insufficient support. The necessity of minimising the residual stresses caused by heat-treatment has been recognised, and investigations have shown that the proper sequence of machining operations is a great aid in equalising the relieving of residual stresses. Compressive residual stresses, which are generally situated at the surface of a forging, are balanced by tensile stresses in the interior part of the forging, and the removal of the compressive stresses by alternate machining on both sides of a forging has assisted greatly in holding distortion to a minimum.

The Astin Case

The case involving Dr. Allen V. Astin, the director of the National Bureau of Standards, which was reviewed in our issue of May 29, 1953, has now been closed with the report by an independent committee of American scientists stating that the "AD-X2" compound was without merit as a battery additive. The committee also found that the tests of the National Bureau of Standards, which previously had found the compound to be ineffective, had been "excellent." The committee recommended that no further tests be conducted on the additive. The report, covering exhaustive investigations of nearly six months, has put an end to a particularly bitter controversy which was waged on a national scale last spring. In a statement accompanying the committee's report, Mr. Sinclair Weeks, the U.S. Secretary of Commerce, said the scientists' evaluation "is an assurance to the public and a source of satisfaction to me and to the Bureau." The report effectively vindicated the judgment of Dr. Astin, who, it may be recalled, was forced to resign his post as a result of the Bureau's findings on the additive. At the time of Dr. Astin's removal, Mr. Weeks criticised the testing standards of the N.B.S. as "not sufficiently objective." Subsequently, following a flurry of protests, Dr. Astin was reinstated on a "temporary" basis and late in August he consented to remain in office indefinitely.

On May 4th, Mr. Weeks asked Dr. Detlev W. Bronk, president of the National Academy of Sciences, to appoint a committee to evaluate the work performed by the Bureau of Standards in relation to the additive and to determine whether additional tests were needed. The committee of ten added to its objectives an appraisal of the additive itself. In its report the committee stated: "From the study and investigations, the committee concluded that the quality of the work of the National Bureau of Standards in the field of lead acid storage battery testing is excellent, and that while Pioneers, Incorporated, the manufacturers of the additive, claim that 'AD-X2' has substantial merit, the relevant data now available to the committee on the effects of 'AD-X2' are adequate to support the position of the Bureau of Standards that the material is without merit." After studying various tests on the additive, some of them favourable to "AD-X2" and some unfavourable, the committee reported that in no case had it found differences between treated and untreated battery cells that were not normally expected. Furthermore, the committee reported those differences noted did not uniformly favour "AD-X2." "We find no data obtained from any well-designed scientific experiment which is inconsistent with the hypothesis that 'AD-X2' behaves like a corresponding mixture of sodium and magnesium sulphates and is substantially neutral in its effect upon a lead acid storage battery," the report concluded.

A Nuclear Power Station

The U.S. Atomic Energy Commission has awarded a contract to the Westinghouse Electric Corporation for the development of an industrial power plant to operate on nuclear energy. It is believed that the atomic pile involved will use enriched uranium 238 as fuel and that the boiler, turbine and generator sections of the plant will be of conventional design. The rated capacity of the unit will be 60MW, it will cost between 20,000,000 and 60,000,000 dollars, it will take from three to four years to design and construct, and it will be situated near one of the large gaseous diffusion plants of the A.E.C.—Oak Ridge, Tennessee; Paducah, Kentucky; or Portsmouth, Ohio.

BULLETIN OF MECHANICAL ENGINEERING EDUCATION.—We have received from the Manchester Municipal College of Technology the fifth bulletin of Mechanical Engineering Education. Amongst the articles is an introduction to non-linear vibration by R. E. D. Bishop, of Cambridge University, and another by C. H. Helmer, University of Southampton, deals with the Stroud system of units.

Industrial and Labour Notes

Overseas Trade

Figures published in the Board of Trade accounts show the value of exports of United Kingdom goods in January as £225,700,000, which was slightly above the December value, but 2 per cent below the monthly average of the fourth quarter of 1953. There were twenty-six working days in January, compared with twenty-five in December. In January last year, however, when there were twenty-seven working days, the value of exports did not exceed £217,700,000.

In the January accounts, the Board of Trade has instituted its new system of classification, which conforms very nearly with the standard international trade classification. The figures reveal an increase in exports of engineering products in January. A total value of £89,000,000 was recorded, which was £8,000,000 or so more than the monthly average in either half of last year. In the machinery division there were increases in January, compared with the first half of 1953, in exports of agricultural and track-laying tractors, in textile machinery and in industrial valves. The January exports of electrical machinery, apparatus and appliances were valued at £15,000,000 and were above the average in either half of last year, and there were also increases in the exports of locomotives and railway vehicles. Exports of aircraft and parts in January, which were valued at £3,000,000, were a little below the average of the first half of last year. Motor-car exports in January, at a value of £8,000,000, were above the monthly rate for the preceding six months, although they were slightly less than in the first half of last year.

Wages and Dividends

In the course of a speech which he made in Glasgow last Friday evening, the Chancellor of the Exchequer, Mr. R. A. Butler, referred to the continuing need for moderation and restraint in respect both of wages and dividends. He recalled that he had repeatedly emphasised the dangers to this country's export trade and to its whole economy if higher money incomes were sought without correspondingly higher production. It was not true, the Chancellor continued, that there had been a runaway increase in dividends, for whilst the total amount paid in dividend had gone up, the actual rate of dividend—that is, the amount distributed as a percentage of the capital employed in industry—had fallen. The Chancellor went on to say that the wage earner's situation was better than it had ever been, but the improvement, he commented, could only be permanent if the country continued to pay its way overseas.

In the same speech, Mr. Butler also referred to Britain's increasingly stern fight to hold export markets, and once more stressed the need for a marked rise in productivity and productive investment. In this country, he said, first priority must be given to development, not only in long-established basic industries, but also in new ones, such as aircraft production, which provided valuable new exports. The renewal and modernisation of industrial plant in the U.S.A. and Germany, the Chancellor went on, together with their volume of savings, and the rate of increase of their production made uncomfortable comparisons with our own. The way must be found to increase our production, efficiency and competitive power.

Low-Grade Ores

The European Productivity Agency of the Organisation for European Economic Co-operation is making arrangements for a mission to visit the U.S.A. in order to study basic research and development in exploiting low-grade ores. It is believed that the findings of this mission can stimulate research which is already being done in Europe, and will also complement the findings of last year's mission to European countries on the same subject.

It is stated that the aim of this proposed mission will be to gather information about basic research carried out by the United States Bureau of Mines and its laboratories and about development work on the results. Visits of European experts will be strictly limited to laboratories and research establishments, and no visits to industrial plants are envisaged, as these were covered by the technical assistance mission which visited the U.S.A. in 1951. The proposal is that the United Kingdom should send a small delegation, not more than two members of it representing firms with mining interests at home and abroad. The mission will probably start during the first week of September and be away, in all, from five to seven weeks. The cost to delegates is expected to be about £300 each. Firms or individuals interested in this mission on low-grade ores are invited to address their inquiries, before March 6th, to the Ministry of Materials, Division 4B, Horseguards Avenue, Whitehall, S.W.1.

Steel Company's Scholarships

It has been announced that the United Steel Companies, Ltd., has endowed a university entrance scholarship, tenable at St. John's College, Cambridge, which will be open to candidates who intend to study physical or mechanical sciences. The scholarship will be offered annually at the open examination for entrance scholarships and exhibitions of St. John's College, and the emolument will be £100 a year, which the College will be entitled to augment to bring it up to a total value of £150. The emoluments will be paid without regard to a scholar's financial circumstances.

The award and administration of the scholarship will be left entirely to the College, with discretion to make modifications to the arrangements in the future in order to preserve the purposes for which the scholarship is founded. The hope is expressed by the United Steel Companies, Ltd., that the scholars may frequently have the intention of entering industry and be likely to rise to positions of responsibility therein. It has been suggested that where the intellectual qualifications of candidates are approximately equal, weight should be given to personal qualities and background which may be judged to fit them to become senior executives in industry. In the endowment of this scholarship there is no stipulation as to the future career of the scholars, although, naturally, the company hopes to make contact with them.

British Steel Industry's Outlook

The February issue of the *National Provincial Bank Review* includes an article by Sir Ellis Hunter which comments on the present prospects of the British steel industry. Sir Ellis says that the denationalisation of the industry is taking place at a time when, in the economic sense, the industry is emerging from the abnormal circumstances of the immediate post-war period into a more settled state of affairs. Although international competition is now keener and prices more competitive than for years past, the demand for British steel at home and abroad, Sir Ellis points out, remains at a record level. He adds that the industry is thus looking forward to a period of active business throughout 1954 and beyond.

Commenting on the European Coal and Steel Community, Sir Ellis suggests that there is no reason to suppose that the competitive ability of the British steel industry *vis-à-vis* that of the Community should in any way deteriorate in the years to come. The British steel industry, he says, has no cause to fear normal competition from the Continent. What it experienced between the wars was abnormal competition, in the sense that Continental steel producers exported to this country at prices below domestic levels and indeed below cost. The British steel industry, Sir Ellis adds, is entitled to expect some safeguard against a repetition of the inter-war conditions, no matter whether this country remains apart from the Schuman Community or moves into some kind of association with it.

Inventions and Designs (Crown Use) Bill

The Engineering Industries Association has sent to the Minister of Supply a statement setting out its criticisms of the provisions of the Inventions and Designs (Crown Use) Bill. This Bill, it may be recalled, is concerned with the use by the Crown of inventions and with the disclosure of industrial information required by the Crown for defence purposes.

The Association says that there appears to be no parliamentary or other control over the issuing of directives for the disclosure of information to any person in any country. Moreover, the Association thinks that the definition of invention and design is very wide and appears to include all processes of manufacture. The Association goes on to submit that there is no provision in the Bill for the person owning information to be notified by the Government department as to the use of that information by third parties, and there is therefore no assurance that appropriate payment can be obtained for the use of the information. It would appear that, under the Bill, a British company may be forced to disclose information which it had obtained or purchased from a foreign company, and the British company may thus be in danger of being sued for wrongful disclosure. The Engineering Industries Association concludes its observations by saying that the main practical objection to the Bill is in the fact that the Government may enforce a disclosure of trade secrets to a competitor. This, the Association comments, is a very serious matter, which should only be possible under circumstances of a far greater degree of emergency than is envisaged in the Bill.

Public Ownership of the Chemical Industry

At the annual conference of the Labour Party last October, there was formally adopted as part of the official programme, a proposal for a substantial degree of public ownership of the chemical industry. This week, Imperial Chemical Industries, Ltd., has published a pamphlet which sets out in some detail the company's views on the matter.

The company's opposition to nationalisation has already been stated, and in this new document the present chairman, Dr. Alexander Fleck, reaffirms the opposition expressed by his predecessors. He points out that nationalisation would tend to stifle commercial and technical initiative, and thus hamper the constant search for new products and processes, for more efficient methods of production and distribution, for more effective methods of management, and for new opportunities in overseas markets. To this, Dr. Fleck adds that " it is most unlikely that research work would continue to be so far-reaching and flexible, and at the same time so closely in touch with practical possibilities." Furthermore, he says, there is the danger that short-term research would be favoured as compared with the long-term research on which ultimate progress so much depends.

As well as commenting in detail on the Labour Party's proposals for the chemical industry, the pamphlet makes some rather more general observations concerning public ownership. It says, for example, that for industries at present in private ownership an atmosphere of confidence is needed. Left alone, private industry will continue to work out priorities according to the demand for its products. It is a fallacious assumption, the pamphlet asserts, that some central Government authority can work out these priorities in detail, whether for home consumption or for export. To attempt to arrange these priorities by central Government decision means over-centralisation and an immense bureaucracy which can only lead to delays, blunders and frustration. Finally, the pamphlet declares that it is a misguided notion that a Government, by planning, can create the conditions in which inventors flourish and new ideas can be developed. The choice of inventions and ideas to be backed by heavy development and capital investment is, it is claimed, a matter for experts and not for politicians.

Notes and Memoranda

Rail and Road

IMPROVEMENTS AT EUSTON.—Following the completion of the £300,000 scheme of improvements to the arrival side at Euston Station, further reconstruction work is now in progress. In this new work the departure platforms Nos. 12–15 are to be widened and repositioned and the tracks relaid to an altered layout. The new platforms are being built with concrete walls, with earth fillings in between, surfaced with paving slabs and tarmacadam. Platforms Nos. 12 and 13 will be widened from 28ft to 30ft and Nos. 14 and 15 from 17ft 9in to 25ft 9in.

HEAVY STEEL WORKS LOCOMOTIVES.—Two 40-ton, four-wheel, diesel-mechanical locomotives were delivered recently by the Hunslet Engine Company, Ltd., for heavy haulage round sharp curves at the County Durham steelworks of the Consett Iron Company, Ltd. The new locomotives have 48½in wheels spread over a 6ft 6in wheelbase and they can negotiate curves of 80ft radius. Power is supplied by a four cylinder Mirrlees "J4" four stroke oil engine which is set to give a top output of 330 b.h.p. at 900 r.p.m. The engine drives through a Hunslet friction main clutch and four speed gearbox, with preselective controls, to a jackshaft from which the final drive to the wheels is through rods. The locomotive track speeds are 4·3, 6·5, 10·2 and 16 m.p.h., and its tractive effort in bottom gear is 22,400 lb.

BASIC ROAD STATISTICS FOR 1953.—The annual handbook, "Basic Road Statistics, 1953," published by British Road Federation, Ltd., 4a, Bloomsbury Square, London, has been restyled "to make a wider appeal among the growing number of people interested in roads and road transport." The latest edition of this publication has been enlarged by the addition of an appendix dealing with Northern Ireland, and two colours are now used to aid the symbolic treatment of figures. The handbook points out that motor taxation in 1952–53 was £360,958,000, while Government allocations for roadworks in that year were less than £33,000,000. It also states that road accidents are estimated to have cost the country £139 million in 1952. The handbook shows that the number of motor vehicles in Great Britain (excluding Government-owned vehicles) totalled nearly 5,000,000 in 1952, at the time of the last census, an increase of some 279,000 over 1951. Diesel-engined vehicles totalled 106,211.

Air and Water

COASTAL MINESWEEPER.—On February 18th H.M. Coastal Minesweeper "Kirkliston" was launched at the Belfast shipyard of Harland and Wolff, Ltd. The ship has a length of 152ft by 28ft 9in beam and is propelled by diesel engines.

HOPPER BARGE.—"Hopper No. 25," which is being built by William Simons and Co., Ltd., for the Clyde Navigation Trustees, was launched on February 8th, complete with all machinery on board. The 1200-ton hopper barge is propelled by two sets of triple expansion engines taking steam at 180 lb per square inch from two cylindrical boilers.

"CUTTY SARK."—On Thursday of last week the "Cutty Sark" left her moorings at Greenhithe and proceeded to a berth in the East India Import Dock as the first stage of her last voyage to her permanent home at Greenwich. The Preservation Fund, it is stated, has reached a total of £170,000 towards the appeal for £250,000 made in April, 1953.

K.L.M. AIRWAYS.—During the year 1953 K.L.M. carried 599,650 passengers, which was 82,575 more than in the previous year. The quantity of freight transported was 14,989,000 kg as compared with 14,349,000 kg in 1952, while the quantity of mail increased by 219,000 kg to 2,196,000 kg. The number of revenue ton kilometres for freight and mail was 39,756,000 and 7,926,000 ton kilometres, respectively. This company has now installed an electronic calculating machine at its main office, The Hague.

CIVIL ENGINEER-IN-CHIEF.—We are informed that the First Lord of the Admiralty has approved the appointment of Mr. M. E. Adams, O.B.E., as Civil Engineer-in-Chief in succession to Sir F. A. Whitaker, K.C.B., who retires on March 31st. Sir Arthur Whitaker, who is a Master of Engineering, joined the Admiralty in 1915 and was made Deputy Civil Engineer-in-Chief in 1934, becoming Civil Engineer-in-Chief six years later. He was made a C.B. in 1941 and promoted to Knight Commander in 1945 and also appointed a Commander of the Legion of Honour for his work on the Mulberry Harbours. The Civil Engineer-in-Chief designate, Mr. M. E. Adams, entered Admiralty service in 1927 and in 1943 was appointed Assistant Civil Engineer-in-Chief in charge of work in the Eastern theatre of war. From 1946 to 1949 he was Deputy Civil Engineer-in-Chief and then left the Admiralty to join a private firm of contractors.

CARGO HANDLING CONFERENCE.—The International Cargo Handling Co-ordination Association has issued a draft programme for the International Technical Conference to be held in Naples from May 31st to June 4th at the Palazzo del Congressi in the grounds of the International Maritime Exhibition. On May 31st there will be a reception of the delegates by the Italian National Committee, followed by various addresses, an official luncheon and a visit to the exhibition. A symposium on an ideal port will be held in the morning of June 1st and a visit to the port of Naples in the afternoon. Papers dealing with some recent devices to facilitate ship loading and discharge, the handling of perishable goods and the trends of development of container traffic will be read on June 2nd, while on the following day some excursions are offered followed by a reception by the Naples Municipality. On the final day, June 4th, there will be a symposium on training, including papers entitled "Training in Cargo Handling at the U.S. Merchant Marine Academy, King's Point," and "Dockers' Training School and Dockers' Apprentice Establishment, Rotterdam." The convention will close with an official luncheon.

AIR SERVICES APPROVED.—The Minister of Transport and Civil Aviation after considering the recommendations of the Air Transport Advisory Council, has approved, subject to certain conditions being satisfied, the operation of an internal service between Newcastle (Woolsington) and Belfast (Nutts Corner) via an optional stop at Glasgow (Renfrew). No traffic rights will be exercised between Glasgow and Belfast except in agreement with B.E.A. The service will be operated by Hunting-Clan Air Transport, Ltd., until March 31, 1960. The Minister has also approved the inclusion of Manchester (Ringway) until March 31, 1961, as either a terminal or an intermediate traffic stop on B.O.A.C.'s normal scheduled services between the United Kingdom and Boston and/or New York, and between the United Kingdom and Bermuda or Nassau; an increase of frequency on the services operated by B.K.S. Air Transport, Ltd., between West Hartlepool (Greatham) and London (Northolt) up to a maximum of twelve return flights weekly and the extension to Nottingham (Tollerton) of the internal services operated by Derby Aviation, Ltd., between Derby and/or Wolverhampton and Jersey. The use of Nottingham is subject to adequate facilities being made available at that aerodrome.

Miscellanea

TUNGSTEN ORE PRICES.—The Ministry of Materials has announced that as from February 22nd its selling price for tungsten ores of standard 65 per cent grade and ordinary quality has been reduced as follows: wolframite from £7 5s. to £6, and scheelite from £7 to £5 15s. per long ton unit delivered consumers' works.

NAPIER "ORYX."—A new Napier power unit, the "Oryx" turbo-gas generator has just been removed from the Secret List. Although details and illustrations are still confidential, it may be said that the Napier "Oryx," as the description suggests, is a gas turbine engine arranged to enable the gas delivered by the unit to be used for propulsion by providing thrust at the rotor tips of helicopters.

WORKS DEVELOPMENT SCHEME OF PRIESTMAN BROTHERS, LTD.—Mr. S. H. Priestman, the chairman of Priestman Brothers, Ltd., announced at the company's annual meeting a plan to develop a 46 acre works site at Marfleet, at a cost of over half a million pounds. This site, lying 5 miles to the east of Hull, has already had a 51,000 square foot shop built on it and it is proposed that the covered area will be more than doubled over the next two years. The scheme includes an office block, canteen, and storage and service buildings, which will allow the company to move its offices and works from Williamson Street.

ASSOCIATED DYNAMO AND MOTOR MANUFACTURERS.—The annual dinner of the Associated Dynamo and Motor Manufacturers (A.D.M.M.) was held in London on February 16th. The Rt. Hon. Lord Sempill, who proposed the toast of the "A.D.M.M.," spoke of the lack of men and production facilities to apply the discoveries made by British scientists, who, he said, were second to none. For example, pioneer work had been done in Britain on printed electronic circuits, but the development of production techniques had been left to the Americans, who had not been slow to exploit them. Mr. J. S. Ramsden, chairman of the A.D.M.M. from 1934 to 1946, replied. The toast of "The Guests" was proposed by the chairman, Mr. F. H. Schroeder, and the response was made by Lieut.-General Sir Thomas Hutton, Director of the British Productivity Council.

Personal and Business

MONO PUMPS, Ltd., is moving to larger premises at 1, Sekforde Street, London, E.C.1.

MR. F. W. BUGLASS has been appointed works director of Percival Aircraft, Ltd., Luton Airport, Beds.

HOLMAN BROS., Ltd., Camborne, Cornwall, has opened a new London office at 44, Brook Street, W.1.

MR. H. VEZEY STRONG, Mr. R. P. Creagh, and Mr. R. R. Miller have resigned from the board of Silentbloc, Ltd.

NEWMAN INDUSTRIES, Ltd., announces the appointment of Mr. L. M. Reay as London sales manager in the electric motor division.

CRANE, Ltd., has opened a new showroom at Great West Road, Brentford, for the convenience of its customers in the Home Counties.

MR. W. D. STIVEN has been appointed commodore chief engineer of the P. and O. Steam Navigation Company. He joined the company in 1914.

CHILTON ELECTRIC PRODUCTS, Ltd., Hungerford, Berks, states that it is opening a London showroom at 19, Old Queen Street, S.W.1 (telephone, Trafalgar 3035).

THE BRITISH TYRE AND RUBBER COMPANY, Ltd., Herga House, Vincent Square, London, S.W.1, announces the appointment of Mr. J. F. MacGillivray as personnel manager.

TEDDINGTON INDUSTRIAL EQUIPMENT, Ltd., has established a Midlands area office at 107, Dale End, Birmingham (telephone, Central 4791). Mr. V. C. Miles is in charge of the office.

MR. A. A. PAGET, chief planning engineer of W. and T. Avery, Ltd., has been appointed works manager of Vandome and Hart, Ltd., North London Iron Works, Wenlock Road, N.1.

SIR REX HODGES, who is retiring from the position of general manager and secretary of the Mersey Docks and Harbour Board, is joining the board of British Insulated Callender's Cables, Ltd., on March 31st.

MARTIN, BLACK AND CO. (WIRE ROPES), Ltd., Coatbridge, Glasgow, announces the appointment of Mr. G. A. Black, Mr. W. Douglas, Mr. John Goodlet, Mr. W. Holloway, jun., and Mr. R. G. Sewell as executive directors.

THE SHELL PETROLEUM COMPANY, Ltd., announces that Mr. P. R. Drew, O.B.E., has been elected to the board of directors of Shell Tankers, Ltd., and also appointed manager of the chartering and freight department.

ROCKWELL MACHINE TOOL COMPANY, Ltd., Welsh Harp, Edgware Road, London, N.W.2, states that it has been appointed sole agent in Great Britain for the BMAG fully automatic boring machine manufactured by Berliner Maschinenbau A.G.

SHEEPBRIDGE ENGINEERING, Ltd., Chesterfield, has made an agreement with the Horix Manufacturing Company, Pittsburgh, U.S.A., for the sole manufacturing and selling rights in the United Kingdom of Horix automatic bottle filling machines.

SHELL-MEX AND B.P., Ltd., announces that Mr. R. Turnbull has been appointed bitumen manager in the eastern division in succession to Mr. R. A. Newstead. Mr. Newstead is remaining in the division as an adviser until his retirement later this year.

MAJOR, ROBINSON AND CO., Ltd., Manchester, has opened a London office at Evelyn House, 62, Oxford Street, W.1 (telephone, Museum 5229). Mr. F. J. Robins, who has been appointed sales director of the company, is in charge of the office.

MR. V. P. HARRIES, Under Secretary (Contracts) in the Ministry of Supply, has been appointed to the board of Power Jets (Research and Development), Ltd., in place of Mr. W. F. Jenkins, who has been appointed to the Department of Atomic Energy.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., Trafford Park, Manchester, states that, following the transfer of Mr. W. L. Beeby to the Edison Swan Electric Company, Ltd., Mr. C. H. Smith has been appointed works engineer and Mr. J. H. Phillips, assistant works engineer.

ASEA ELECTRIC, Ltd., has formed a new company, entitled Asea Electric (Ireland), Ltd., to take over its interests in the Irish Republic. Mr. J. A. V. McEvoy is the managing director of the new company, the headquarters of which are at 4, Mount Street Crescent, Dublin.

ELLIOTT BROTHERS (LONDON), Ltd., Century Works, Lewisham, S.E.13, states that it has concluded a licence and technical agreement with The Bristol Company of Waterbury, Connecticut, U.S.A., and has acquired the business of Bristol's Instrument Company, Ltd., of Weymouth.

THE BRITISH ELECTRICITY AUTHORITY states that its commercial manager, Mr. E. R. Wilkinson, has been seconded to the International Bank for Reconstruction and Development to assist in the technical and economic appraisal of certain international electrical power developments.

THE TELEGRAPH CONSTRUCTION AND MAINTENANCE COMPANY, Ltd., Greenwich, S.E.10, states that Mr. J. N. Dean has been appointed deputy chairman. The executive duties of the board will in future be carried out by a managing board of which Mr. Dean, as the company's chief executive, will be chairman.

MASSEY-HARRIS-FERGUSON (SALES), Ltd., Coventry, states that Mr. Noel Newsome now has responsibility for the public relations and publicity of the group throughout the eastern hemisphere. Mr. Newsome joined Harry Ferguson, Ltd., in 1948. Mr. A. B. Lees, who joined Harry Ferguson, Ltd., in the same year, now takes charge of market research for Massey-Harris-Ferguson in the eastern hemisphere.

MARRYAT AND SCOTT, Ltd., Wellington Works, Hounslow, states that Mr. Murray D. Scott has retired from the active management, but continues to serve as chairman of the company. Mr. L. W. Honey and Mr. L. J. Gooch have been appointed joint managing directors, the former operating from the Hounslow works and the latter from the company's London office at 40, Hatton Garden, E.C.1.

Contracts

THE B.B.C. announces that contracts for the provision and erection of the masts for the transmitting aerials at the permanent medium-power television stations at Rowridge (Isle of Wight), Pontop Pike (near Newcastle upon Tyne), and North Hessary Tor (South Devon) have been placed with British Insulated Callender's Construction Company, Ltd., 21, Bloomsbury Street, London, W.C.1. Similar contracts for the provision and erection of masts for the permanent medium-power television stations at Divis (Northern Ireland) and Core Hill (near Aberdeen) have been placed with J. L. Eve Construction Company, Ltd., 17, Hillside, London, S.W.19. All the masts will be generally similar in construction and with the exception of that for North Hessary Tor, which will be 750ft high, they will have a height of 500ft. Design work on these masts is to start immediately.

British Patent Specifications

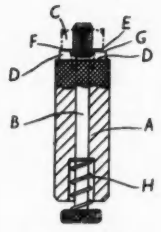
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

TOOLS AND WORKSHOP APPLIANCES

701,812. May 2, 1951.—Gauges for Testing the Relation between the Face of Threaded Nuts and their Thread, Cyril Lorenzo Field, 5, Badsey Close, Northfield, Birmingham, 31.

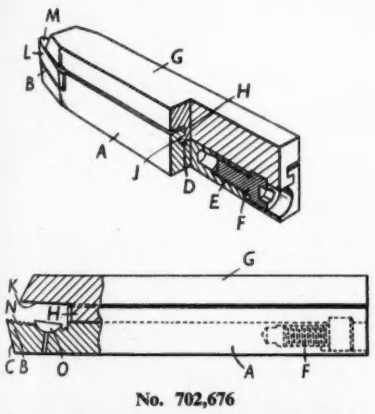
As shown in the drawing, a sleeve *A* has slidably mounted in it a rod *B* on to one end of which the nut *C* to be inspected is screwed. The threaded end of the rod is tapered and truncated, whilst the other end is formed with a knob for turning it. The end of the sleeve adjacent to the threaded end of the rod *B* is formed with a ridge *D*, the top of which is inclined in relation to the axis of the rod *B*, the angle of the inclination being equal to the tolerance allowed on the face of the screwed nut *C* under test. It will be seen, therefore, that on the nut being screwed on to the rod with the under surface *E* of it abutting the highest portion *F* of the ridge *D* of the sleeve *A*, rotation of the nut will indicate whether the surface of the nut at any point is raised off the highest portion of the ridge. Contact of the nut face on the lowest portion *G* of the ridge indicates that the maximum amount of tolerance has been exceeded. It will be seen which part of the ridge *D* the surface of the nut contacts by the light passing therethrough, without the necessity of using the usual feeler gauge. The screwed rod *B* may be controlled by the spring *H* to hold the surface *E* in contact with the ridge on the sleeve. In the specification a modification of the invention is also shown.—*January* 6, 1954.



No. 701,812

702,676. March 6, 1951, and August 14, 1951.—Tool-Holders, The Birmingham Small Arms Company, Ltd., Armoury Road, Small Heath, Birmingham. (*Inventor: Arthur Blackmore.*)

As illustrated in the drawings, the main body *A* of the holder is substantially square and has formed on it a tapered nose portion *B* having a flat tool-seating surface *C* downwardly inclined from the nose. Formed in the upper part of the body is a longitudinal open-ended channel *D* and in the end of the body remote from the nose portion is a tapped hole *E* to receive a clamping screw *F*. The other part *G*, which forms the top of the holder and also constitutes part of the wedge, corresponds in length and width to the main body part, and has formed on the under side a depending longitudinal rib *H* provided with flanges *J*, engaging with the grooves in the body, whereby the part *G* is slidably secured to the body of the holder. The rib *H* terminates a short distance from the front end of the part *G* where an inclined surface *K* is formed to engage with the top surface *L* of the tool bit *M* which, when in position on its support, is substantially level with the top face of the main body. With the upper wedge *G* slidably mounted on the main body of the holder and a tool bit placed in position on its support, the wedge is driven forwards when the screw *F* is turned, thereby forcing the inclined face *K* at the front end of the wedge *G* into engagement with the inclined upper face *L* of the tool bit *M* and so applying a clamping pressure between the lower face of the bit and its support. Transverse serrations are formed on the lower face of the tool bit to engage serrations *N* on the face of the support.—*January* 20, 1954.

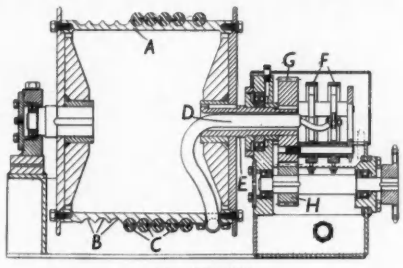


No. 702,676

CRANES AND LIFTING GEAR

702,414. August 27, 1951.—Construction of Cable Drums, The Butterley Company, Ltd., Ripley, and Archibald George Westmoreland, of the company's address.

The invention relates to drums for the coiling and uncoiling of cable such as for an electric magnet suspended from the hook of an overhead crane. The drawing shows a cable drum *A* which has a helical groove *B* to receive a cable *C* the end of which *D*, passes through the hollow trunnion of drum *E*, and is connected to slip rings *F*. These are mounted upon a gear wheel *G* keyed on the trunnion and driven by a pinion *H* upon a countershaft driven by a chain wheel. The drive to the drum from the chain wheel includes the reversing gear and pinion to ensure that the cable is correctly laid in the helical groove in the drum. Three alternative arrangements of feed wheels and a plain drum are given in the specification.—*January* 13, 1954.

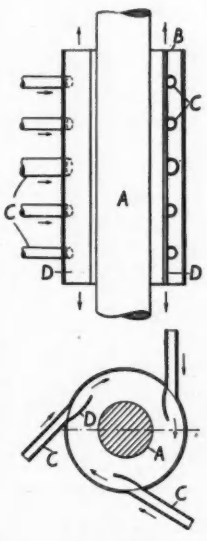


No. 702,414

METALLURGY

702,687. June 12, 1951.—Cooling of Ingots in the Continuous Casting of High-Melting Metals, Gebr. Böhler and Co. Aktiengesellschaft, 12, Elisabethstrasse, Vienna, 1, Austria.

The invention consists in a method of cooling an ingot outside the mould during the continuous casting of high melting metals, more particularly iron and steel, characterised in that a gaseous coolant, more particularly air, is led to the ingot in several supply panels and flows round the ingot in the form of a spiral. As the drawings illustrate, the ingot *A* is surrounded by the cooling sprinkler *B* into which open the pipes *C* for the supply of the coolant. As will be seen from the lower view, the coolant supply pipes *C* are arranged tangentially and are provided with deflecting devices *D*. The coolant leaves the sprinkler, which is open at the top and bottom. In the construction shown in the drawings the pipes *C* in the central supply plane are of larger cross section than those in the other supply planes. It is also possible, more especially for vertical casting, to make the supply pipes in at least one of the upper supply planes of larger cross section than those below, and to make the inlet opening for the ingot narrower, for example, by partially covering the cooling sprinkler, so that the coolant flows substantially downwards.—*January* 20, 1954.

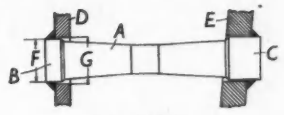


No. 702,687

RAILWAY ENGINEERING

702,520. January 24, 1950.—Locomotive Fireboxes, Arnold Tross (Austrian), Schumannstrasse 4, Munich 27, Germany.

The invention relates to staybolts in the firebox portion of locomotive boilers. The drawing shows a part sectional view of a staybolt and the method of connection to inner and outer firebox shells. The staybolt *A* has its heads *B* and *C* rigidly fixed into the inner and outer firebox shells *D* and *E* by welding. The difference between the bolt head diameter *F* and the diameter *G* of the corresponding hole in, at least, the inner shell *D* is not less than 0·5mm and preferably not larger than 2mm. This clearance takes up that amount by which the thermal expansion within the fire zone of the inner shell exceeds the expansion of the surrounding zones and of the foundation ring. Upsetting effects between bolt head and plate, such as are caused by unrelieved thermal expansion stresses and which lead to permanent deformations or even, when the firebox cools down, to cracks at the edges of the holes, are thus prevented. This measure represents a deliberate departure from the common practice of fitting the bolt as tightly into the hole as the assembly work permits. Relieving the thermal expansion stress also prevents the bulging of the individual staybolted areas, and reduces the bulging of the side plate as a whole. This, in turn, considerably reduces the S-shaped bending of the stays which results from the lateral shifting of the stay ends relative to each other, in the peripheral zones of the bulging plates. Both effects substantially reduce the bending stresses in the plates and in the stays, and prevent incipient cracks and fractures.—*January* 20, 1954.

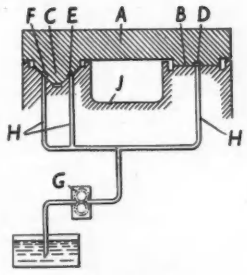


No. 702,520

MACHINE TOOLS

702,584. February 25, 1952.—Lubrication of Sliding Surfaces of Machine Tools, The Churchill Machine Tool Company, Ltd., Atlantic Street, Broadheath, near Manchester. (*Inventor: George Herbert Asbridge.*)

The object of the invention is to provide between sliding surfaces an oil film independent of any relative movement of the surfaces and of the load on them. Referring to the drawing, the machine table *A*, which has a flat surface at *B* and a V sliding surface at *C*, has a longitudinal groove *D* extending for a distance short of the ends of the table, the groove being midway between the sides of the flat surface. There are similar grooves *E* and *F* along the two sides of the V bearing surface. Oil is fed to the grooves from a pump *G* through pipes or passages *H* in the machine bed *J*. The distance of the ends of the grooves *D*, *E* and *F* from the ends of the table should be substantially equal to the distance of the sides of the grooves from the sides of the surfaces in which they are situated. The grooves are so positioned that they are always in communication with the passages *H* and never become uncovered during movements of the table. When the pump delivers oil into the grooves these rapidly fill from end to end and pressure builds up until it is able to ease the table off its ways when oil escapes between table and bed, forming an oil film on which the table can be freely moved, such oil film being created without dependence on movement of the table. As the grooves are positioned midway between edges of the table from which the oil can escape, the oil film formed is of uniform thickness and the rate of leakage or escape of oil from the film is substantially uniform around the edges.—*January* 20, 1954.



No. 702,584

TESTING INSTRUMENTS AND DEVICES

702,622. November 7, 1951.—Detection of Leaks in Vessels, C. A. Parsons and Co., Ltd., Heaton Works, Newcastle upon Tyne, 6. (*Inventors: Albert Edward Martin and John Smart.*)

In carrying the invention into effect nitrous oxide obtained from a cylinder is charged into a vessel intended to be gastight until a concentration of the order of 2 per cent is obtained in it. Air is then introduced until the pressure rises to 15 lb per square inch above atmospheric, so that the final concentration of nitrous oxide in the vessel is about 1 per cent. Introduction of air to build up this pressure also effectively mixes the nitrous oxide and air in the vessel. Air containing about 1 per cent of nitrous oxide will now issue from any point of leakage. Air

from the vicinity of a suspected leak is passed through an infra-red gas analyser by connecting a small electrically driven suction pump to one outlet of the sample tube in this instrument, the other outlet going to a flexible pipe of rubber, the open end of which is brought into the vicinity of the suspected leak so that air in the neighbourhood is drawn steadily through the gas analyser. Infra-red gas analysers are particularly sensitive to nitrous oxide since this gas has intense absorption at 4·50μ and 7·78μ in the infra-red region of the spectrum. The sensitivity of such a gas analyser is such that 0·001 per cent nitrous oxide in air will give a distinct indication so that dilution of the gas issuing from the leak in the ratio 1000 : 1 before entering the gas analyser will not cause the presence of nitrous oxide to be missed.—*January* 20, 1954.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

TOLERANCES FOR MOULDINGS IN THERMOSETTING MATERIALS

No. 2026 : 1953. Price 3s. A widely used practice has been to specify tolerances such as plus or minus 0·005in for decimal dimensions and plus or minus $^1/_{64}$in for fractional dimensions for plastics mouldings of thermosetting materials. These figures are arbitrary and bear no relation to conditions peculiar to plastics moulding technique. A system has therefore been drawn up of standard tolerances for thermosetting mouldings, having a technical instead of an arbitrary basis. It should, however, be noted that the measurement of moulded pieces can never attain great accuracy because minor dimensional changes which take place during ageing, the rate of which is affected by ambient conditions. Tolerances to nearer than 0·001in are thus likely to be unrealistic because of these changes.

In the specification the four classes of tolerance provided range from the narrowest possible limit commensurate with closely controlled and supervised processing at all stages of production to wide variations where dimensions are not important. The relationship between the various classes is such that the widest tolerance is four times that of the closest, the other two classes being intermediate.

The document explains that in each class the tolerance will depend on the method of production of the moulding and a table, with drawing, is provided to assist the designer. Examples are also given of calculating the tolerances on specific items.

TUBULAR HEAT EXCHANGERS FOR USE IN THE PETROLEUM INDUSTRY

No. 2041 : 1953. Price 12s. 6d. This is a further standard in the series that is being prepared for equipment used in the petroleum industry. In view of the international character of the petroleum industry, careful consideration was given to the standards of the Tubular Exchanger Manufacturers' Association of the U.S.A. for "R" class heat exchangers because of their use in the petroleum and chemical industries and the advantage of ensuring interchangeability in practice between equipment produced by American and British manufacturers. The British Standard applies to shell and tube heat exchangers for use in the petroleum industry and covers dimensions and manufacturing requirements peculiar to the tubular heat exchangers. It should also be read in conjunction with B.S. 1500 (Provisional), "Fusion-Welded Pressure Vessels for Use in the Chemical and Allied Industries" or any other suitable code which may be specified. The document is divided into various sections dealing with general requirements, materials, construction and workmanship, scantlings, testing, marking, and inspection and testing facilities. Appendices are included giving details of materials to be used, dimensions of shell, shell cover and channel flanges, as well as pressure temperature ratings for tube plates and flanges. An appendix gives the information which it is suggested should be supplied by the purchaser or manufacturer, as the case may be.

PHOSPHOR BRONZE SPRING WASHERS FOR GENERAL ENGINEERING PURPOSES

No. 2061 : 1953. Price 2s. 6d. Although phosphor bronze washers have a more restricted field than those of steel, they have a definite advantage where resistance to corrosion, non-magnetic or similar distinctive properties are required. The range of nominal sizes for the three washer types dealt with in the tables, i.e. single coil, square and rectangular sections and double coil, varies from 10BA to $\frac{3}{4}$in. for the first and 6BA to $\frac{3}{4}$in for the other two.

A number of manufacturing and testing requirements are given and there is a complete analysis of the phosphor bronze to be used. The general adoption of the range of wire sections presented in this new specification would be of considerable assistance to the manufacturers of spring washers in that they would be enabled to reduce, considerably, the large number of different sections they have been compelled to carry in the past.

With the exception of the aircraft industry, for which the washers are not intended, users in the field of general engineering will find in this standard and its companion, B.S. 1802, spring washers suitable for all normal sizes and requirements.

RUST, ACID AND HEAT-RESISTING STEEL WIRE FOR SPRINGS

No. 2056 : 1953. Price 2s. 6d. This standard covers the same kinds of steel as B.S. 1554, "Rust, Acid and Heat-Resisting Steel Wire," and specifies the requirements for such wire when it is to be used in the form of springs.

CHAINS AND WHEELS FOR SINGLE BOTTLE WIDTH SLAT CONVEYORS

No. 2075 : 1954. Price 2s. 6d. Although this document has been prepared under the authority of the Dairying Industry Standards Committee, the Food Machinery Association and the Mineral Water Engineers Association collaborated and it is therefore hoped that it will prove of advantage to all industries which use this class of conveyor for transporting bottles of about the same size as milk bottles.

Owing to the fact that the adoption of a standard form of integral-slat conveyor would necessitate some modification to all existing designs, the committee decided to confine this British Standard to the roller chain and slat band chain conveyors. The specification details the materials and dimensions of both the chains and the slats, together with tolerances.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases, the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

CLEVELAND INSTITUTION OF ENGINEERS

Mon., March 1st.—Scientific and Technical Institution, Corporation Road, Middlesbrough, "Some Starting Up and Operating Experiences at the Abbey Melting Shop of the Steel Company of Wales, Ltd.," A. J. Kesterton, 6.30 p.m.

INCORPORATED PLANT ENGINEERS

To-day, Feb. 26th.—BIRMINGHAM BRANCH: Imperial Hotel Temple Street, Birmingham, "Tacoma Bridge Failure," B. G. Ough; "Fatigue Fractures," J. Lang, 7.30 p.m.
Mon., March 1st.—W. AND E. YORKS BRANCH: The University, Leeds, Annual General Meeting, 7.30 p.m.
Wed., March 3rd.—KENT BRANCH: Bull Hotel, Rochester, Annual General Meeting, 7 p.m.
Thurs., March 4th.—PETERBOROUGH BRANCH: Eastern Gas Board's Demonstration Theatre, Peterborough, "Welding for Maintenance," J. S. Skelton, 7.30 p.m.——SOUTHAMPTON BRANCH: Polygon Hotel, Southampton, Annual General Meeting, 7.30 p.m.
Mon., March 8th.—DUNDEE BRANCH: Mathers Hotel, Dundee, Annual General Meeting, 7.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Sat., March 6th.—LANCASHIRE BRANCH: Engineers' Club, Albert Square, Manchester, "Inter-Relation of Combustion and Metallurgical Reactions in the Cupola," D. Fleming, 3 p.m.

INSTITUTE OF MARINE ENGINEERS

To-day, Feb. 26th.—JUNIOR LECTURE, MERSEYSIDE AND N.W. SECTION: Technical College, Bolton, "Launching of Ships," R. S. Hogg, 3 p.m.

INSTITUTE OF METALS

Tues., March 2nd.—OXFORD LOCAL SECTION: Cadena Café, Cornmarket Street, Oxford, "Thermochemistry of Alloys," A. R. Harding, 7 p.m.
Thurs., March 4th.—BIRMINGHAM LOCAL SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "Metals in the Oil Industries," 6.30 p.m.——LONDON LOCAL SECTION: 4, Grosvenor Gardens, S.W.1, "High-Temperature Corrosion," J. P. Dennison, 6.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Mon., March 1st.—SCOTTISH CENTRE: North British Station Hotel, Edinburgh, "Trends in Vehicle C.L. and Petrol Engine Lubrication," F. Lawrence, 7.30 p.m.
Tues., March 2nd.—EASTERN CENTRE: Duke's Head Hotel, King's Lynn, "Tyres: Their Manufacture and Maintenance," R. S. Hall, 7 p.m.
Thurs., March 4th.—WESTERN CENTRE: Grand Hotel, Bristol, "Some Factors Affecting Fuel Consumption," W. T. Skinner, 7.30 p.m.

INSTITUTE OF WELDING

Thurs., March 4th.—N. LONDON BRANCH: Manson House, Portland Place, W.1, "The Welding of Copper and its Alloys," R. L. Bernhardt, 7 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Tues., March 2nd.—Geological Society, Burlington House, Piccadilly, London, W.1, "Design Aspects of Vinylchloride Manufacture," A. H. Goodliffe and Ir. Noorduyn, 5.30 p.m.

INSTITUTION OF CIVIL ENGINEERS

To-day, Feb. 26th.—YORKSHIRE ASSOCIATION: Blue Bell Hotel, Scunthorpe, "Reconstruction of a Soaking Pit Building," H. C. Husband and K. H. Best, 6.30 p.m.
Tues., March 2nd.—ROAD MEETING: Great George Street, Westminster, London, S.W.1, "British Highway Bridge Loadings," William Henderson, 5.30 p.m.
Fri., March 5th.—N.W. ASSOCIATION: Engineers' Club, Albert Square, Manchester, "Design of Foundations in Relation to Superficial Geological Deposits in the North-West Area," B. M. Evans, 6.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

To-day, Feb. 26th.—N.E. STUDENTS' SECTION: Grey Hall, King's College, Newcastle upon Tyne, "Arc Control in High-Voltage Air-Break Circuit Breakers," D. Legg, 6.30 p.m.
Mon., March 1st.—LONDON STUDENTS' SECTION: Savoy Place, London, W.C.2, "Industrial Consumer Installation Practice," J. J. Peacock, 6.30 p.m.——S. MIDLAND CENTRE: James Watt Memorial Institute, Great Charles Street, Birmingham, "Research in the Electrical Manufacturing Industry," L. J. Davies, 6 p.m.
Tues., March 2nd.—MEASUREMENTS SECTION: Savoy Place, London, W.C.2, "Current and Power Relationships in the Measurement of Iron Losses in a Three-Limbed Transformer Core," F. Brailsford, "An Automatic Plotter for Magnetic Hysteresis Loops," H. McG. Ross, 5.30 p.m.
Wed., March 3rd.—S.W. SCOTLAND SUB-CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, Parsons Memorial Lecture, "Continuity of Electrical Supply," H. Leyburn, 7 p.m.——LONDON STUDENTS' SECTION: Public Library, Chelmsford, "Metallic Resistance at High Frequency," A. D. Stevens, 7 p.m.
Thurs., March 4th.—ORDINARY MEETING: Savoy Place, London, W.C.2, "Submerged Telephone Repeaters for Shallow Water," R. J. Halsey and F. C. Wright, "The Netherlands-Denmark Submerged-Repeater System," A. H. Roche and F. O. Roe; "British Post Office Standard Submerged-Repeater System for Shallow-Water Cables, with special reference to the England-Netherlands System," D. C. Walker and J. F. P. Thomas, 5.30 p.m.
Mon., March 8th.—INFORMAL MEETING: Savoy Place, London, W.C.2, Discussion on "How Can Electrical Methods Enhance Industrial Productivity," opened by Sir Henry Clay, 5.30 p.m.

INSTITUTION OF ENGINEERING INSPECTION

Tues., March 2nd.—S.W. BRANCH: Grand Hotel, Broad Street, Bristol, "Engineers at War (Part 2): Pipe Lines to Battle," W. H. Hooper, 7.30 p.m.
Wed., March 3rd.—BIRMINGHAM BRANCH: Chamber of Commerce, New Street, Birmingham, Films, 7.30 p.m.
Thurs., March 4th.—LONDON BRANCH: Royal Society of Arts, John Adam Street, Adelphi, W.C.2, "Co-operative Research in the Rubber Industry," J. R. Scott, 7 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Feb. 26th.—GENERAL MEETING, JAMES CLAYTON LECTURE: 1, Birdcage Walk, Westminster, London, S.W.1, "Nuclear Reactors and Power Production," Sir Christopher Hinton, 5.30 p.m.——N.E. BRANCH: Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, "Operation of a Marine Gas Turbine Under Sea Conditions," John Lamb and R. M. Duggan, 6.30 p.m.
Mon., March 1st.—MIDLAND BRANCH: Neville Hall, Westgate Road, Newcastle upon Tyne, "Operation of a Marine Gas Turbine Under Sea Conditions," John Lamb and R. M. Duggan, 6.30 p.m.——S. WALES A.D. GRADUATES' SECTION: Park Hotel, Cardiff, "The Young Engineer as a Supervisor," T. W. Currie, 7 p.m.
Tues., March 2nd.—EASTERN A.D. GRADUATES' SECTION: W. H. Allen, Sons and Co., Ltd., Bedford, "A Study in American Management Techniques," S. H. Jones, 7.30 p.m.——LONDON A.D. GRADUATES' SECTION: 1, Birdcage Walk, London, S.W.1, "Heat Transfer to Boiling Liquids," M. Ruddick, 6.30 p.m.
Wed., March 3rd.—SOUTHERN BRANCH: The University, Southampton, "Rotating Wing Aircraft and Their Future Development, with special reference to Their Application to Industry," A. McClements, 7 p.m.
Thurs., March 4th.—EASTERN BRANCH: Hoffman's Social Hall, Chelmsford, "Some Practical Applications of Strain Gauges in Industry," J. R. Bryant, 7.30 p.m.——N.W. BRANCH: Engineers' Club, Albert Square, Manchester, "Casting by the Shell Moulding Process," C. M. Dixon and R. F. Bushnell, 6.45 p.m.
Fri., March 5th.—N.E., A.D. GRADUATES' SECTION: Gas Board Showrooms, 30, Grainger Street, Newcastle upon Tyne, Annual General Meeting, "Some Notes on Cranes," W. I. O. Moffat, 7 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, Feb. 26th.—W. WALES SECTION: Mackworth Hotel, Swansea, "Machine Tools for Precision Work in the Clock and Watch Industry," H. Matthews, 7 p.m.
Wed., March 3rd.—NOTTINGHAM SECTION: Victoria Station Hotel, Milton Street, Nottingham, Annual General Meeting, Films, 7 p.m.
Thurs., March 4th.—GLASGOW SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, Annual General Meeting and Open Discussion, 7.30 p.m.——LONDON SECTION: Powers-Samas Accounting Machines, Ltd., Aurelia Road, Croydon, Surrey, "Production Control as Applied to Small and Medium-Sized Companies," F. T. Hunter, 7 p.m.——N. IRELAND SECTION: Royal Avenue Hotel, Belfast, Annual General Meeting and Informal Evening, 7.30 p.m.——READING SECTION: Great Western Hotel, Reading, "Shell Moulding Process," D. N. Buttrey, 7.30 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

To-day, Feb. 26th.—MIDLAND COUNTIES BRANCH: James Watt, Memorial Institute, Great Charles Street, Birmingham, "A Method of Structural Analysis by Large-Scale Models," C. B. Brewington and J. W. Fortey, 6 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Feb. 26th.—INFORMAL MEETING: Townsend House, Greycoat Place, London, S.W.1, "An Introduction to the Shell Moulding Process," A. S. Ladley, 7 p.m.
Wed., March 3rd.—MIDLAND SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "Developments and Future Possibilities in Electricity Generation," Sir John Hacking, 7 p.m.
Fri., March 5th.—Townsend House, Greycoat Place, London, S.W.1, Film Evening, 7 p.m.

NATIONAL TECHNICAL GROUPS, ELECTRICAL POWER ENGINEERS' ASSOCIATION

Mon., March 1st.—LONDON LOCAL GROUP: York Room, Caxton Hall, S.W.1, "Hydrogen Cooled Alternators," H. M. Oliver, 7 p.m.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, Feb. 26th.—Mining Institute, Newcastle upon Tyne, "Correlation of Model and Ship Trials of a Shallow-Draught Rhine Vessel," W. P. A. Van Lammeren and J. D. Van Manen, 6.15 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., March 2nd.—SECTION LECTURE: 4, Hamilton Place, London, W.1, "Metal Sandwich Construction," F. Tyson, 7 p.m.
Thurs., March 4th.—MAIN LECTURE: Royal Fort Physics Laboratory, Bristol, First Barnwell Memorial Lecture, G. P. Bulman, 7 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Mon., March 1st.—ORDINARY GENERAL MEETING: 12, Great George Street, London, S.W.1, "Land Use and the Life of Buildings," J. F. Q. Switzer, 5.30 p.m.

SOCIETY OF ENGINEERS

Mon., March 1st.—ORDINARY MEETING: Geological Society, Burlington House, Piccadilly, London, W.1, "Progress in Petroleum Refining," C. R. Young, 5 p.m.